ONTARIOPOWER GENERATION

Report

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Nuclear Environment

ENVIRONMENTAL RISK ASSESSMENT REPORT FOR PICKERING NUCLEAR

P-REP-07701-00007 R001

REPORT PREPARED FOR:

ONTARIO POWER GENERATION
889 Brock Road
Pickering, ON
L1W 3J2

REPORT PREPARED BY:

Ecometrix Incorporated
www.ecometrix.ca
Mississauga, ON

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ENVIRONMENTAL RISK ASSESSMENT REPORT FOR PICKERING NUCLEAR

Winnie Lee
Project Manager

Rina Parker
Project Sponsor

Don Hart
Senior Advisor/Reviewer

Revision Number	Date	Comments
R0	27-Apr-2022	Initial issue of report.
R1	31-Mar-2023	To address regulatory comments on R0.

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

AAQC	Ambient Air Quality Criteria
ADCP	Acoustic Doppler Current Profiler
AE1	Age 1 Equivalent
ALARA	As Low as Reasonably Achievable
ATSDR	Agency for Toxic Substances and Disease Registry
BAF	Bioaccumulation Factor
BCF	Bioconcentration Factor
BC MOE	British Columbia Ministry of the Environment
BMF	Biomagnification factor
BOD	Biochemical Oxygen Demand
BTEX	Benzene, Toluene, Ethylbenzene, and Xylenes
BV	Benchmark Value
CAAQS	Canadian Ambient Air Quality Standards
CANDU	CANada Deuterium Uranium
CCME	Canadian Council of Ministers of the Environment
CCW	Condenser Cooling Water
CEAA	Canadian Environmental Assessment Act
CNSC	Canadian Nuclear Safety Commission
COD	Chemical Oxygen Demand
COG	CANDU Owners Group
COPC	Contaminant of Potential Concern
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
COSSARO	Committee on the Status of Species at Risk in Ontario
CSA	Canadian Standards Association
CSM	Conceptual Site Model
CTM	Critical Thermal Maximum
CWQG	Canadian Water Quality Guidelines
DC	Dose Coefficient
DF	Dilution Factor
DFO	Fisheries and Oceans Canada
DRL	Derived Release Limit
DSC	Dry Storage Container
DSM	Dry Storage Module
DWSP	Drinking Water Surveillance Program
EA	Environmental Assessment
EC/HC	Environment Canada/Health Canada
ECA	Environmental Compliance Approval
ECCC	Environment and Climate Change Canada
EcoRA	Ecological Risk Assessment

ELC	Ecological Land Classification
EMP	Environmental Monitoring Program
ERA	Environmental Risk Assessment
ESA	Endangered Species Act
ESDM	Emissions Summary and Dispersion Modelling
ESL	Effects Screening Limits
EV	Exposure Values
FCSAP	Federal Contaminated Sites Action Plan
FDS	Fish Diversion System
FEQG	Federal Environmental Quality Guideline
FUMP	Follow-Up and Monitoring Program
GCDWQ	Guidelines for Canadian Drinking Water Quality
GWMP	Groundwater Monitoring Program
GWPP	Groundwater Protection Program
HC	Health Canada
HHRA	Human Health Risk Assessment
HQ	Hazard Quotient
HT	Elemental Tritium
HTO	Tritium Oxide
HTS	Heat Transport System
HU	Hydrostratigraphic Unit
IAEA	International Atomic Energy Agency
IARC	International Agency for Research on Cancer
IBI	Indices of Biological Integrity
ICRP	International Commission on Radiological Protection
ILCR	Incremental Lifetime Cancer Risk
ILW	Intermediate Level Waste
iPWQO	Interim Provincial Water Quality Objectives
IRIS	Integrated Risk Information System
ISO	International Organization for Standardization
LCV	Lowest Chronic Value
LEL	Lowest Effect Level
LLW	Low Level Waste
LOAEL	Lowest Observed Adverse Effect Level
LOEC	Lowest Observed Effect Concentration
LSA	Local Study Area
MDL	Method Detection Limit
MECP	Ministry of Environment, Conservation and Parks
mfp	Mixed Fission Products
MISA	Municipal Industrial Strategy for Abatement
MNRF	Ministry of Natural Resources and Forestry
MOE	Ontario Ministry of Environment
MOEE	Ontario Ministry of Environment and Energy
MOECC	Ontario Ministry of Environment and Climate Change

MWAT	Maximum Weekly Average Water Temperatures
NCRP	National Council on Radiation Protection and Measurement
NEW	Nuclear Energy Worker
NOEC	No Observed Effect Concentration
NOAEL	No Observed Adverse Effect Level
NO	Nitric oxide
NO_2	Nitrogen dioxide
NO_x	Nitrogen oxides
NMOR	N-nitrosomorpholine
NSCA	Nuclear Safety and Control Act
NWTP	New Water Treatment Plant
OBT	Organically Bound Tritium
ODWQS	Ontario Drinking Water Quality Standards
OMNR	Ontario Ministry of Natural Resources
OPG	Ontario Power Generation
P&SO	Plants and Soil Organisms
P2	Pollution Prevention
PAH	Polycyclic Aromatic Hydrocarbon
PHC	Petroleum Hydrocarbons
PN	Pickering Nuclear
PNGS	Pickering Nuclear Generating Station
POI	Point of Impingement
POR	Point of Reception
POW	Plane of Window
PWMF	Pickering Waste Management Facility
PWQO	Provincial Water Quality Objective
QA	Quality Assurance
QSAR	Quantitative Structure-Activity Relationship
RBE	Relative Biological Effectiveness
RfC	Reference Air Concentration
RLWMS	Radioactive Liquid Waste Management System
RSA	Regional Study Area
RSL	Regional Screening Levels
SAR	Species at Risk
SARO	Species at Risk in Ontario
SQG	Soil Quality Guidelines
SSA	Site Study Area
SSC	Structures, Systems, and Components
STDM	Short-Term Daily Maximum
TCEQ	Texas Commission on Environmental Quality
TF	Transfer Factor
TRC	Total Residual Chlorine
TRCA	Toronto and Region Conservation Authority
TRV	Toxicity Reference Value

TSD	Technical Support Document
TSS	Total Suspended Solids
UCLM	Upper Confidence Limit of the Mean
UIL	Upper Incipient Lethal
UNSCEAR	United Nations Scientific Committee on the Effects of Atomic Radiation
UPP	Upgrading Plant Pickering
U.S. EPA	United States Environmental Protection Agency
UTM	Universal Transect Mercator
VEC	Valued Ecosystem Component
VOC	Volatile Organic Compound
WHO	World Health Organization
WSP	Water Supply Plant
WWMF	Western Waste Management Facility

SYMBOLS

Human Non-Radiological Parameters

C_{air}	=	air concentration (µg/m^3).
P_{01}	=	transfer parameter from source to air (s/m^3)
X_0	=	emission rate (g/s)
C	=	concentration of contaminant in drinking water (mg/L)
IR	=	receptor intake rate (L/d)
RAF_{GIT}	=	absorption factor from the gastrointestinal tract (unitless)
D_2	=	days per week exposed•(7 days)$^{-1}$ (d/d)
D_3	=	weeks per year exposed•(52 weeks)$^{-1}$ (wk/wk)
D_4	=	total years exposed to site (years) (for carcinogens only)
BW	=	body weight (kg)
C_{foodi}	=	concentration of contaminant in food i (mg/kg)
IR_{foodi}	=	receptor ingestion rate for food i (kg/d)
RAF_{GITi}	=	relative absorption factor from the gastrointestinal tract for contaminant i (unitless)
D_i	=	days per year during which consumption of food i will occur (d/a)
LE	=	life expectancy (years) (for carcinogens only)
P_{01}	=	transfer parameter from source emission to air

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

D_{int}	=	internal radiation dose (µGy/d)
D_{ext}	=	external radiation dose (µGy/d)
D_{NG}	=	noble gas dose (Gy/a)
DC_a	=	effective dose coefficient for a semi-infinite cloud for a mixture of noble gases (Sv/a)/(Bq•MeV/m^3)
DC_{int}	=	internal dose coefficient ((µGy/d)/(Bq/kg))
DC_{ext}	=	external dose coefficient ((µGy/d)/(Bq/kg))
$DC_{ext,w}$	=	external dose coefficient (in water)
$DC_{ext,s}$	=	external dose coefficient (in soil) ((µGy/d)/(Bq/kg))
$DC_{ext,ss}$	=	external dose coefficient (on soil surface) (µGy/d)/(Bq/kg))
C_{airNG}	=	noble gas concentration in air (Bq·MeV/m3)
C_m	=	media concentration (Bq/L or Bq/kg)
C_f	=	average concentration in food (Bq/kg fw)
C_w	=	water concentration (Bq/L)
C_s	=	soil/sediment concentration (Bq/kg fw)
C_t	=	whole body tissue concentration (Bq/kg fw)
C_x	=	concentration in the ingested item x (Bq/kg fw)
OF_w	=	occupancy factor in water
OF_{ws}	=	occupancy factor at water surface
OF_s	=	occupancy factor in soil/sediment
OF_{ss}	=	occupancy factor at soil/sediment surface
BAF	=	bioaccumulation factor (L/kg or kg/kg)
BMF	=	biomagnification factor (unitless)
I_x	=	ingestion rate of item x (kg fw/d)
TF	=	ingestion transfer factor (d/kg)
DW_a	=	dry/fresh weight ratio for animal products (kg-dw/kg-fw)
$1-DW_a$	=	water content of the animal (L water /kg-fw)
$1-DW_p$	=	water content of the plant/food (L water /kg-fw plant)
BAF_{a_HTO}	=	aquatic animal BAFs for tritium (L/kg-fw)
BAF_{p_HTO}	=	plant BAF for tritium (L/kg-fw)
P_{air_plant}	=	transfer from air to plant (m^3/kg-fw)
P_{air_spw}	=	transfer from air to soil pore water (m^3/L)
θ	=	volumetric moisture content of soil (m^3 water/m^3 soil)
p_b	=	bulk density of the soil (kg/m^3)
k_{af}	=	fraction of food from contaminated sources
k_{aw}	=	fraction of water from contaminated sources (assumed to be 1)
f_{OBT}	=	fraction of total tritium in the animal product in the form of OBT as a result of HTO ingestion
f_{w_w}	=	fraction of the animal water intake derived from direct ingestion of water
f_{w_pw}	=	fraction of the animal water intake derived from water in the plant feed
f_{w_dw}	=	fraction of the animal water intake that results from the metabolic decomposition of the organic matter in the feed
$P_{HTOwater\_animal}$	=	transfer of HTO to animals through water ingestion (L/kg-fw)
$P_{HTOfood\_animal}$	=	transfer of HTO to animals through food ingestion

$P_{HTOsoil\_plant}$	=	transfer of HTO from soil to plant
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)
S_a	=	stable carbon content in the animal (gC/kg-fw)
S_p	=	stable carbon content in the food (gC/kg-fw)
$BAFa_{C14}$	=	C-14 BAF for aquatic animals, invertebrates, and plants (L/kg-fw)
$P_{C14food\_animal}$	=	transfer of C-14 from food to animals

Ecological Non-Radiological Parameters

C_x	=	concentration in the ingested item (x) (mg/kg)
D_{ing}	=	dose from ingestion pathway (mg/kg body weight/d)
I_x	=	ingestion rate of item x (kg/d)
W	=	body weight of consumer (kg fw)
ΔT	=	change in temperature (ºC)

EXECUTIVE SUMMARY

The following document is the Environmental Risk Assessment (ERA) for Pickering Nuclear (PN), which meets the requirements of the Canadian Standards Association (CSA) N288.6-12 standard "Environmental risk assessments at Class I nuclear facilities and uranium mines and mills" (CSA, 2012). The standard requires a human health risk assessment (HHRA) and an ecological risk assessment (EcoRA), for both radiological and non-radiological contaminants and physical stressors. The results of the ERA inform the environmental monitoring programs (EMP) and effluent monitoring programs, as per CSA N288.4-10 "Environmental monitoring programs at Class I nuclear facilities and uranium mines and mills" (CSA, 2010) and CSA N288.5-11 "Effluent monitoring programs at Class I nuclear facilities and uranium mines and mills" (CSA, 2011), respectively. These programs can also inform the ERA by providing information on effluent concentrations and loadings, and by providing environmental data to assist in model calibration and validation. This ERA focuses on the 2016 to 2020 period.

The 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, with six operating CANada Deuterium Uranium (CANDU) pressurized heavy water generating stations, and two units in safe storage.

In 2014, an updated integrated EcoRA and HHRA was prepared consistent with CSA N288.6-12 guidance, using monitoring data from the five-year period of 2007 to 2011. The ERA identified a number of areas where supplementary monitoring studies were recommended including collecting updated soil data on the PN site, collecting lake water samples along the PN discharge channels for low-level hydrazine detection, and collecting sediment and water samples from the northern section of the Frenchman's Bay wetland. These supplementary studies (also known as the baseline environmental sampling program) were carried out in 2014 and 2015 to reduce uncertainty in the ERA and to support future PN licensing activities. The baseline environmental sampling program included collection of lake surface water data, sediment and surface water data from Frenchman's Bay, stormwater data, soil data, and noise data.

Overall, the data considered for this ERA includes results of the 2014/2015 sampling programs and routine environmental and effluent monitoring data from 2016 to 2020 including data from the Environmental Monitoring Program for radiological contaminants; waterborne emissions data from Environmental Compliance Approval (ECA) monitoring programs; and predicted airborne emissions through annual Emission Summary and Dispersion Modelling (ESDM) reports.

The overall goals of this ERA are:

- To establish an updated environmental baseline condition for the PN site.
- To support assessment of the future shutdown and safe storage of PN.
- To prepare the ERA in general accordance with the CSA N288.6-12 Standard.

- To provide focus for the environmental monitoring program on relevant contaminants of potential concern, media, and ecological and human receptors.

The specific objectives of this ERA, consistent with CSA N288.6-12, are:

- To evaluate the risk to relevant human and ecological receptors resulting from exposure to contaminants and physical stressors related to the PN site and its activities.
- To recommend potential further monitoring or assessment as needed based on the results of the ERA.

Human Health Risk Assessment (HHRA)

Predicted exposures to sources from PN were evaluated on the basis of toxicological effects from non-carcinogenic contaminants of potential concern, potential cancer risk from carcinogens, and potential radiation exposure from radionuclides.

Human Receptors

Human receptors evaluated included off-site members of the public, specifically those potential critical groups used for dose calculations in the annual Ontario Power Generation (OPG) EMP reports within approximately 20 km of the PN site, including:

- C2 Correctional Institution;
- Local Residents;
- Local Farms;
- Local Dairy Farms;
- Sport Fishers; and
- Off-site Industrial/Commercial Workers.

These six potential critical groups were used for the exposure assessment for both radiological and non-radiological contaminants of potential concern.

On-site receptors were not addressed in the HHRA, since OPG's Health and Safety Management System Program and Radiation Protection Program ensure safe exposure levels on site.

Screening of Contaminants of Potential Concern for Human Health

The facilities at the PN site emit radiological and non-radiological contaminants to air, water, soil, and groundwater in the normal course of operations. Measurements and modeled concentrations of contaminants of potential concern were screened against available screening benchmarks that are protective of human health to determine if any contaminants of potential concern required further study in the context of HHRA. Table ES-1 provides a summary of the contaminants of potential concern carried forward for further quantitative assessment in the HHRA.

Selected radiological stressors are considered to be of public interest and therefore, were carried forward quantitatively in the HHRA. The radionuclides selected for use in Derived Release Limit (DRL) calculations were considered appropriate for assessment in the HHRA, as discussed in Section 3.1.2.5.

Groundwater within the PN site is not used for human consumption. Since the PN site is fully developed, there is minimal opportunity for contact with on-site soil. The PN site is not a source of dust generation; therefore, there would be limited impacts to off-site soil.

Physical stressors such as noise are relevant to human receptors. There are periods where noise levels at Points of Reception in the vicinity of PN were above the Ontario Ministry of the Environment and Climate Change Environmental Noise Guideline, Stationary and Transportation Sources – Approval and Planning NPC 300 Class 1 and Class 2 sound level limits; therefore, noise was carried forward as a physical stressor in the HHRA.

Table ES-1: Summary of Contaminants of Potential Concern (COPC) Selected for Human Health Risk Assessment

Category	Radiological COPC	Non-Radiological COPC
Air	tritium, noble gases, carbon-14, radioiodines (mixed fission products), mixed beta/gamma particulates (represented by cobalt-60)	nitrogen oxides (NO_x)
Surface water	tritium, carbon-14, gross beta/gamma (represented by cesium-134)	hydrazine
Groundwater	None	None
Stormwater	None	None
Soil	cesium-134, cesium-137, cobalt-60, iodine-131, carbon-14, tritium	None
Noise	Yes	

Results of HHRA

Non-radiological HHRA

The complete exposure pathways that were assessed in the non-radiological HHRA included:

- Inhalation (nitrogen oxides) for all six human receptor groups;
- Water ingestion (hydrazine) for the Urban Resident, Correctional Institution, and Industrial/Commercial Worker; and
- Fish ingestion (hydrazine) for the Sport Fisher and Urban Resident.

Potential risks to human receptors were characterized quantitatively in terms of Hazard Quotients for non-carcinogens (nitrogen oxides) and Incremental Lifetime Cancer Risks for potential carcinogens (hydrazine). Consistent with CSA N288.6-12, the acceptable risk levels are less than 0.2 for non-cancer risk (Hazard Quotient) and less than a cancer risk of 10^{-6} (Incremental Lifetime Cancer Risk). The results of the HHRA are as follows.

- No chronic risk to human receptors is expected from nitrogen oxides released from the site to air. To reduce uncertainty around short-term exposure concentrations, it is recommended that future air dispersion modelling scenarios include estimation of the predicted air concentrations at the potential critical group receptor locations.
- No risk to human receptors via drinking water. The incremental lifetime cancer risk for hydrazine in drinking water was less than the acceptable cancer risk level of 10^{-6} for the Urban Resident and Correctional Institution resident based on the upper confidence limit of the mean (UCLM) concentrations of hydrazine in the Condenser Cooling Water (CCW) discharge. Risks were calculated incorporating the understanding that hydrazine is known to degrade rapidly under chlorinated conditions typically used for treatment/distribution of drinking water (EC and HC, 2011). A dilution factor of 42 was used to estimate intake concentrations at the Ajax Water Supply Plant based on CCW discharge concentrations (EC and HC, 2011).
- Using a conservative assumption that 100% of the fish in the Sport Fisher's diet is obtained from fish collected 500m from the CCW discharge, the incremental lifetime cancer risk to the Sport Fisher exceeded the acceptable cancer risk level, considering UCLM concentrations of hydrazine in the CCW discharge. Realistically, a fisher's diet would likely include fish harvested from various locations including those unaffected by PN emissions.

Radiological HHRA

For exposure of human receptors to radiological contaminants of potential concern, the relevant exposure pathways and human receptors (potential critical groups) were those presented in the annual OPG EMP reports. Radiological dose calculations followed the methodology outlined in CSA N288.1-14 and N288.1-20. The annual dose to the critical group (the Urban Resident adult) during this five-year period ranged from 1.2 to 2.1 microSieverts, approximately 0.2% of the regulatory public dose limit of 1 mSv/a and approximately 0.1 % to 0.15% of the dose due to background radiation. Since the critical groups receive the highest dose from PN, the demonstration that they are protected implies that other receptor groups near PN or farther away are also protected.

The Sport Fisher may receive a dose up to 0.063 microSieverts per annum from exposure to the Pickering Waste Management Facility (PWMF) (Phase I and Phase II) when it is at full capacity, adjusted for occupancy from the dose presented in the PWMF Safety Report (OPG, 2018a); however, this is still a small fraction of the regulatory public dose limit. The Sport Fisher's total dose is still below the reported PN public dose.

Noise

Annual Acoustic Assessment Reports prepared for PN and the Environmental Compliance Approval for Air and Noise, issued by the Ontario MECP demonstrate that PN operates in compliance within applicable regulatory noise limits and therefore, adverse effects are not expected (OPG, 2011a, 2019a, 2020a, 2021a).

Through a review of noise monitoring data in combination with site observations, the occasional periods of elevated sound levels are not likely associated with PN activities and, therefore, it is not expected that noise from PN activities is having a direct adverse effect on human receptors near the PN site.

Ecological Risk Assessment (EcoRA)

Valued Ecosystem Components

The assessment for the EcoRA focused on the nearshore Lake Ontario (generally in the area surrounding the PN outfalls), the PN site, and Frenchman's Bay. Valued ecosystem components were selected for dose and risk analysis because they are known to exist on-site, and/or are representative of major taxonomic/ecological groups, major pathways of exposure, or have a special importance or value. The model used for assessment of dose and risk is either specific to the selected valued ecosystem component species, or is a more generic biota assessment model that is appropriate to a number of valued ecosystem components with similar exposure characteristics. Table ES-2 shows the selected valued ecosystem components and the assessment models used in estimating their contaminant of potential concern exposure, dose and risk. Protection of the valued ecosystem components implies that other species in the same valued ecosystem component category are also protected.

Table ES-2: Summary of Valued Ecosystem Components and their Assessment Models used in the EcoRA

VEC Category	Assessment Model	VEC
Aquatic Invertebrates	Benthic Invertebrate	Benthic Invertebrates
Aquatic Plants	Aquatic Plant	Narrow-leaved Cattail
Amphibians and Reptiles	Benthic Fish	Midland Painted Turtle
		Northern Leopard Frog
Fish	Benthic Fish	American Eel
		Brown Bullhead
		Round Whitefish
		White Sucker
	Pelagic Fish	Emerald Shiner
		Lake Trout
		Northern Pike
		Smallmouth Bass
		Walleye
Riparian Birds	Trumpeter Swan	Trumpeter Swan
	Ring-billed Gull	Ring-billed Gull

VEC Category	Assessment Model	VEC
	Common Tern	Common Tern
	Bufflehead	Bufflehead
Riparian Mammals	Muskrat	Muskrat
Terrestrial Invertebrates	Soil Invertebrate	earthworms
Terrestrial Plants	Grass/Shrub	Chokecherry
		New England Aster
		Sandbar Willow
	Pine	Eastern Hemlock
		Pine
		Red Ash
Terrestrial Birds	Red-winged Blackbird	Red-winged Blackbird
	Red-tailed Hawk	Red-tailed Hawk
Terrestrial Mammals	Red Fox	Red Fox
	Meadow Vole	Meadow Vole
	White-Tailed Deer	White-Tailed Deer

A number of threatened and endangered species have been identified within the PN Terrestrial Site Study Area during the 2016 to 2020 time period, including Barn Swallow, Chimney Swift, Least Bittern, Butternut, American Eel, and Blanding's Turtle. Each of these species was assigned a surrogate species for the EcoRA.

Assessment endpoints are attributes of the receptors to be protected in environmental programs (Suter et al., 1993). The purpose of an ERA is to evaluate whether these environmental protection goals are being achieved or are likely to be achieved. The assessment endpoint for all receptors in this ecological risk assessment is population abundance. The assessment endpoint for the identified species at risk is the individual, since effects on even a few individuals of species at risk would not be acceptable.

Screening of Contaminants of Potential Concern for Ecological Assessment

The same monitoring data sources previously screened for the HHRA were screened for the EcoRA using the more conservative of available federal and provincial guidelines and objectives as screening criteria. If there was no such guideline or objective, screening criteria were obtained from the literature, and/or derived using federally and/or provincially accepted methods. For contaminants of potential concern where these criteria were not available, upper estimates of background concentrations or conservative toxicity benchmarks (e.g., no effects levels) were used as screening criteria. Maximum measured concentrations of parameters in surface water, sediment, soil, and air were compared to the selected screening criteria to determine the list of contaminants of potential concern. Contaminants were also retained if no screening criteria were available or if they are considered of public interest (e.g., radionuclides).

Table ES-3 provides a summary of the contaminants of potential concern carried forward for further quantitative assessment in the EcoRA.

Surface water and sediment data were collected in the summer of 2015 from Frenchman's Bay and a large number of contaminants of potential concern exceeded screening levels. This is not uncharacteristic for an area such as Frenchman's Bay that is highly influenced by urban runoff. An assessment was performed in Appendix E to determine the proportion of the overall risk to aquatic receptors at Frenchman's Bay that can be attributed to PN.

Certain pathways were considered minor (the pathway has a negligible contribution to dose/risk compared to other pathways) or incomplete (a receptor is not exposed to this pathway) and therefore, were not evaluated. For ecological receptors, the air pathway is a minor exposure pathway relative to soil and food ingestion exposure. Ecological exposure to contaminants of potential concern from on-site groundwater was not evaluated since there are no complete exposure pathways for ecological receptors to site groundwater.

Thermal stressors and entrainment and impingement were carried forward for assessment in the EcoRA since they are widely recognized as being of primary concern in nuclear power plants, as recommended by CSA N288.6-12. Other physical stressors such as noise, wildlife strikes with vehicles and bird/bat strikes on buildings were screened out and were not carried forward for further assessment in the EcoRA.

Table ES-3: Summary of Contaminants of Potential Concern and other Physical Stressors Selected for the Ecological Risk Assessment

Category	Radiological COPC	Non-Radiological COPC
Air	noble gases (represented by argon-41) (PN site)	sulphur dioxide
Surface water	tritium, carbon-14, gross beta-gamma (represented by cobalt-60), cesium-134, cesium-137 (Lake and Frenchman's Bay)	hydrazine, total residual chlorine, morpholine (CCW to Lake); copper (Lake) total aluminum, iron and sodium (Frenchman's Bay)
Groundwater	None	None
Stormwater	None	None
Sediment	carbon-14, cesium-134, cesium-137, cobalt-60 (Frenchman's Bay)	aluminum, bismuth, boron, cadmium, calcium, chromium, copper, iron, lead, manganese, nickel, phosphorous, thorium, tin, zinc, total organic carbon (Frenchman's Bay)
Soil	tritium, carbon-14, cesium-134, cesium-137, cobalt-60 (PN site)	cyanide, arsenic, copper, lead, zinc, and petroleum hydrocarbon F4 (PN site)
Physical Stressor (Noise, Bird Strikes/Wildlife Collisions)	None	
Physical Stressors	impingement/entrainment	
	thermal plume	

Results of the EcoRA

Non-radiological EcoRA

The potential for ecological effects was assessed by comparing exposure levels to toxicological benchmarks and characterized quantitatively in terms of Hazard Quotients (HQ). A Hazard Quotient greater than 1 indicates a need to more closely assess the risk to the concerned valued ecosystem component.

Atmospheric Contaminants

No effects are expected from long-term exposures to sulphur dioxide for ecological receptors at the PN site, considering the maximum concentration at the property boundary (i.e., the point of impingement concentration) has not exceeded Ambient Air Quality Criteria for the past four years, and the highest concentration from 2016, adjusted to an annual average, does not exceed the World Health Organization no-effect levels (WHO, 2000).

Outfall

Maximum and UCLM measured concentrations of morpholine in lake water measured near the outfall and in CCW discharges did not exceed their benchmark values for the receptors of interest.

The benthic invertebrate community is not expected to be affected by the maximum concentrations of hydrazine, copper and total residual chlorine (TRC) at the outfall.

Effects are not expected for the benthic invertebrate community due to copper exposure in sediment, since the estimated sediment concentration is below the sediment benchmark for copper.

Effects are not expected for fish due to TRC exposure in the lake. Although the UCLM concentration of TRC based on measurements of discharges at the outfall exceeded the benchmark value for fish, it is expected that concentrations would rapidly dilute in the lake, and as fish swim around a wider area than the outfall, the UCLM concentration is an overestimation of their exposure.

The American Eel is identified as a species at risk; therefore, the assessment endpoint is the health of the individual. The American Eel is likely not at risk from PN operations. As discussed above, the fish benchmark was exceeded in the outfall for UCLM measured water concentrations of TRC. However, it is expected that concentrations would be diluted in the lake. Further, since fish swim around a wider area, they are unlikely to be exposed to UCLM concentrations.

Overall, the risk to fish from exposure to chemical releases at the outfall is low, and fish are not expected to experience any adverse effects due to non-radiological releases from PN operations.

Frenchman's Bay

Concentrations of hydrazine, morpholine, TRC, and sodium at Frenchman's Bay did not exceed their respective benchmarks for the ecological receptors evaluated at Frenchman's Bay.

Aquatic plants and the benthic invertebrate community are not expected to be at risk at Frenchman's Bay, and the overall contribution from PN operations to the risk is low.

The maximum and UCLM measured iron concentrations in water at Frenchman's Bay were above the benthic invertebrate benchmark, but the maximum and UCLM measured iron concentrations in sediment at Frenchman's Bay did not exceed the sediment benchmarks for benthic invertebrates.

The results of the EcoRA for the riparian mammals and birds at Frenchman's Bay with a risk (HQ) estimated as being above the acceptable level of 1 are summarized below:

- Muskrat from aluminum (maximum and UCLM).
- Trumpeter Swan from iron (maximum and UCLM).
- Bufflehead from aluminum and iron (maximum and UCLM).
- Common Tern from iron (maximum).
- Ring-billed Gull from iron (maximum and UCLM).

Many of these receptors would not reside at Frenchman's Bay exclusively; therefore, the results of the EcoRA are conservative. Overall, while metal effects on a few individuals may occur in Frenchman's Bay, effects on their larger populations are not expected.

Least Bittern was identified as a species at risk observed on the PN Terrestrial Site Study Area; therefore, the assessment endpoint is the health of the individual. The surrogate species in this ERA is the Common Tern. Although the Hazard Quotient for the Common Tern exceeded the acceptable risk level of 1 for maximum concentrations of iron in Frenchman's Bay, UCLM concentrations did not exceed the acceptable risk level of 1. Since the Common Tern (and Least Bittern) is mobile, UCLM exposure is more representative than maximum exposure. As such, the Least Bittern (represented by the Common Tern) is likely not at risk from iron exposure in Frenchman's Bay.

Pickering Nuclear Site

In general, soils on site that exceed benchmark concentrations are localized, suggesting the influence of past industrial operations rather than deposition from atmospheric sources. As such, accumulation of contaminants of potential concern in soil over time is not expected.

The 2015 soil sampling program focused on areas of previously identified contamination. Although, soil sampling only occurred in areas identified as potential habitat, many of these areas on the PN site are not likely to be frequented by the selected Valued Ecosystem Components since they are near PN operations and not in highly vegetated areas.

The results of the EcoRA for the terrestrial VECs at the PN site with a risk (HQ) estimated as being above the acceptable level of 1 are summarized below:

- Earthworm from measured soil concentrations for copper (maximum), zinc (maximum and UCLM), and petroleum hydrocarbon F4 (maximum and UCLM).
- Terrestrial plant from measured soil concentrations for arsenic (maximum), copper (maximum), zinc (maximum and UCLM), and petroleum hydrocarbon F4 (maximum).
- Meadow Vole from copper (maximum).
- Red-winged Blackbird from copper (maximum), lead (maximum), and zinc (maximum and UCLM).
- Red-tailed Hawk from lead (maximum), and zinc (maximum).
- White-Tailed deer from copper (maximum) and zinc (maximum).

Although localized effects to individual earthworms/plants may occur, the earthworm community and terrestrial plant population on the site as a whole are not expected to be affected.

Risks to mammals and birds on the PN site are considered unlikely, based on the results above. Acceptable risk levels were not exceeded for mammals or birds exposed to UCLM concentrations in soil, with the exception of the Red-winged Blackbird for zinc. These receptors, with the exception of the Meadow Vole which has a small home range, are highly mobile and are unlikely to be exposed to the maximum concentrations for the entire year. Residency at the PN site has been assumed to be 1, despite the fact that soil is inaccessible at most areas of the site due to the existing infrastructure. Any effects to individual mammals or birds on the PN site are localized, and the populations on the site as a whole are not expected to be affected.

Barn Swallow is identified as a species at risk; therefore, the assessment endpoint is the health of the individual. The surrogate species in this ERA is the Red-winged Blackbird. As discussed above, the Red-winged Blackbird exceeded the acceptable risk level of 1 for maximum concentrations of copper, lead, and zinc in soil. However, based on UCLM concentrations, Hazard Quotients for copper and lead did not exceed the acceptable risk level of 1. Since birds are mobile, UCLM exposure is more representative than maximum exposure. Additionally, the metal uptake into insect food is conservative since insects have less direct contact with soil than earthworms. As such, the Barn Swallow is likely not at risk from PN operations.

Butternut trees are identified as a species at risk; therefore, the assessment endpoint is the health of the individual. The surrogate species in this ERA is Red Ash (terrestrial plant). While individual trees may be potentially exposed to concentrations above the soil benchmark, there are no trees in the areas of maximum soil concentrations on the PN site. Therefore, Butternut is not at risk in the localized areas of benchmark exceedance.

Radiological EcoRA

Radiation dose benchmarks of 400 microGray per hour (9.6 milliGray per day) and 100 microGray per hour (2.4 milliGray per day) (UNSCEAR, 2008) were selected for the assessment of effects on aquatic biota and terrestrial biota, respectively, as recommended in the CSA N288.6-12 standard (CSA, 2012).

Outfall

There were no exceedances of the radiation dose benchmarks for the aquatic or riparian biota at the outfall location including fish, benthic invertebrates, and Ring-billed Gull.

Frenchman's Bay

There were no exceedances of the radiation dose benchmarks for any aquatic or riparian receptors at Frenchman's Bay.

Pickering Nuclear Site

There were no exceedances of the radiation dose benchmark for terrestrial biota on the PN site including earthworms, terrestrial plants, Meadow Vole, Red-winged Blackbird, Red Fox, Red-tailed Hawk, and White-tailed Deer.

Pickering Waste Management Facility

The maximum dose rate to any ecological VEC residing in close proximity to the PWMF could be up to 0.012 milliGray per day, which is below the 2.4 milliGray per day radiation benchmark for terrestrial biota.

Thermal Effects

Cooper (2013) evaluated lake temperatures in the vicinity of the PN U5-8 discharge. Temperature results at locations in the thermal plume and in reference areas (Thickson Point and Bonnie Brae Point) were compared to thermal criteria (maximum weekly average water temperature and short-term daily maximum criteria) for spawning and embryo-larval periods, and juvenile and adult stages to determine Hazard Quotient values. A Hazard Quotient above 1 is indicative of potential adverse effects from the thermal plume. For fish spawning and embryo-larval development, Cooper (2013) found that the highest Hazard Quotients were marginally above 1 in the plume, but usually were very similar in the reference area.

OPG (OPG, 2018b, 2020b) evaluated the effect of lake water temperature from the thermal plume at PN on Round Whitefish embryo survival for the winters of 2018-2019 and 2019-2020 using a thermal survival model. Round Whitefish embryos are of particular interest as Round Whitefish is considered to be sensitive to elevated water temperatures during the winter months. The model used a revised Hybrid Block 1 Model and the Candu Owners Group (COG) Block 3 Model, where Block 1 refers to the early incubation period of Round Whitefish embryos and Block 3 refers to late incubation period. The estimated survival losses at the plume stations compared to the reference stations (Thickson Point and Bonnie Brae) was 1.3% in 2018-2019, and 0.9% in 2019-2020. These values for survival loss are all below a survival loss of 10%, the recommended threshold for no-effect on Round Whitefish embryo survival (OPG, 2018b). Therefore, the thermal plume from PN is not having an effect on Round Whitefish embryo survival.

OPG has chosen a conservative value of 7°C for a plume temperature at which there could be a possible indication of acute temperature effects. While short-term exceedances above 7°C have occurred, with the longest consecutive period being 26 hours, these short-term exceedances are believed to have no adverse effects on the development of Round Whitefish embryos (OPG, 2020b).

For fish growth (juvenile and adult), Cooper (2013) found that the highest Hazard Quotients were marginally above 1 in the plume for Lake Trout, but were less than or equal to reference values for this species. Therefore, it is unlikely that there are any effects arising from the thermal plume in the lake for juvenile or adult stages of any fish species.

Within the discharge channel, Smallmouth Bass and Emerald Shiner are occasionally exposed to temperatures that exceed their thermal criteria relevant to fish growth. These events are of short duration and never more than a few degrees above criteria. They are localized to the discharge channel and would have no adverse effect on the larger fish populations. In general, it is likely that a net benefit in growth of these species occurs during the summer period as a result of elevated temperatures in the thermal plume.

Entrainment and Impingement

In 2009, in response to an order by the Canadian Nuclear Safety Commission (CNSC) to reduce impingement by 80%, OPG installed a fish diversion system consisting of a barrier net surrounding the intake structure of PN. No reasonable technological solution is available to reduce entrainment by 60% (OPG, 2012a), but these losses are counterbalanced by the offset measures approved by Fisheries and Oceans Canada (DFO) in the PN *Fisheries Act* Authorization.

A *Fisheries Act* Authorization for PN operational activities was issued to OPG by DFO on January 17, 2018, associated with the continual intake of cooling water from Lake Ontario. An annual impingement monitoring report is submitted to DFO to satisfy conditions of the Authorization. The *Fisheries Act* Authorization included a 2-year biomass condition, where consultation with DFO is required if the combined biomass across all species and ages is over 3,619 kg/yr in two consecutive years (OPG, 2020c).

In 2016, biomass lost to impingement was reduced by 88% relative to baseline, exceeding the 80% reduction target. A high level of impingement was observed in 2017 due to a singular fish impingement event in November that was reported to CNSC and DFO. Outside of this event, however, impingement in 2017 was one of the lowest impingement years on record.

Impingement trends over the 2018-2020 period are compared against the 3,619 kg two-year all-ages threshold as per Condition 3.2.1.1. of the *Fisheries Act* authorization. Impingement estimates provided in 2018-2019 indicate an exceedance of the two-year all-ages threshold, and DFO was notified. Further evaluation by Patrick (2020) concluded that the exceedances did not appear to be caused by PNGS operations. In 2020, impingement estimates were less than 3,619 kg, and therefore impingement was below the all-ages two-year threshold.

Recommendations

In order to clarify risk in future human and ecological assessments, the following specific recommendations for monitoring or desktop studies are provided:

- To reduce uncertainty regarding the short-term nitrogen oxide concentrations at the locations of the Sport Fisher and other potential critical groups, it is recommended that future air dispersion modelling scenarios include estimation of the predicted air concentrations at the potential critical groups. Currently, the point of impingement concentrations at the property boundary have been assumed for the Sport Fisher, but it is unclear whether this concentration is appropriate to assess the short-term inhalation risks at their location, 500 m off shore. These refined predicted concentrations can then be used to refine the short-term risk estimates for all potential critical group locations in the ERA.

- Following the 2017 ERA, Environment and Climate Change Canada (ECCC) recommended that future ERA iterations use existing habitat information to estimate the percentage of warmwater fish habitat (i.e., Emerald Shiner, Smallmouth Bass) that could be affected by the discharge. The merits and limitations of this recommendation were discussed in a January 31, 2022 meeting between OPG, ECCC and CNSC. It was agreed by all parties that the limitations outweighed the benefits and, therefore, no further analysis by OPG would be conducted.

- Although site soil data from 2015 confirms localized areas of contamination (Site 14 SS3, SS5, SS6, GMS-28, and GMS-31, as shown on Figure 4.9), no specific monitoring or remediation is recommended at this stage, as the contamination will be addressed during decommissioning of the PN site. According to the preliminary decommissioning plan for the PN site all contamination exceeding the clearance levels for a 'brown field' site will be removed from the site or remediated on site in order to restore the site to a state suitable for other OPG uses; clearance levels will be developed prior to decommissioning (OPG, 2016a).

- Consistent with the requirements of CSA N288.6-12 clause 11.1 to periodically review changes to the facility, the expansion of PWMF Phase II will likely result in changes to the stormwater catchments in the East Complex. The appropriate stormwater outfalls in the East Complex should be reviewed and sampled accordingly to be representative of the catchment areas after the completion of PWMF Phase II expansion. Included in this study should be consideration of the catchment areas 11, 12, and 14-16A as shown on Figure 3.5. At the present time, further stormwater sampling has been postponed until the PWMF Phase II expansion is further along. Gross beta-gamma in stormwater was monitored and reported quarterly over the 2016-2020 period; however, in 2021 OPG determined that no routine monitoring is required given the robust design of the used fuel dry storage containers (DSCs) and absence of liquid inside the DSCs during dry storage (OPG, 2021b). Following their review of the 2017 ERA, CNSC and ECCC recommended that a stormwater sampling plan be included in future ERA submissions. OPG plans to carry out this recommendation prior to and for inclusion in the 2027 ERA.

- It is recommended that OPG continue to engage with local Indigenous communities to develop ongoing and meaningful dialogue, and in particular, to engage prior to/during the preparation of the next ERA to incorporate Indigenous Knowledge and/or perspectives, as available. It is recommended that future ERAs include a section in the report that discusses what was heard from the engagement activities and how this feedback has been considered in the assessment.

Conclusion

Overall, the PN site is operating in a manner that is protective of human and ecological receptors residing in the surrounding area.

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1.0 Introduction

1.1 Background

The *Nuclear Safety and Control Act* (NSCA) mandates the Canadian Nuclear Safety Commission (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" (CNSC, 2020).

The Canadian Standards Association (CSA) N288.6-12 standard (re-affirmed in 2017) provides guidance to be applied to the preparation of environmental risk assessment (ERA) for Class I nuclear facilities (CSA, 2012). The standard calls for both ecological risk assessment (EcoRA) and human health risk assessment (HHRA), for both radiological and non-radiological contaminants and physical stressors. The CSA has also published N288.4-19 (CSA, 2019) and N288.5-11 (CSA, 2011) standards on environmental monitoring programs (EMP) and effluent monitoring programs. These standards recommend that effluent and environmental programs are designed, in part, to address risk issues identified by ERA. These programs can also inform the ERA by providing information on effluent concentrations and loadings, and by providing environmental data to assist in model calibration and validation.

This ERA has been prepared to be compliant with CSA N288.6-12 (CSA, 2012) and also meets the requirements for an ERA outlined in Section 4.1 of REGDOC-2.9.1, version 1.1, "Environmental Protection: Environmental Principles, Assessments and Protection Measures (CNSC, 2017a). The ERA has been developed with current science and current regulatory attitudes in mind.

1.1.1 Review of Past Environmental Assessments

Pickering A Return to Service (PARTS) Environmental Assessment

In 2000, an environmental assessment (EA) was prepared under the Canadian Environmental Assessment Act (CEAA) to return PN Generating Station A (U1-4) to service (OPG, 2000). The Commission issued its decision on the environmental assessment in February 2001. Based on the information contained in the EA, and taking the proposed mitigation measures into account, the CNSC decided that the return to service of PNGS-A was not likely to cause significant adverse environmental effects. Following their decision, the CNSC amended the operating licence to allow the station to restart after identified improvements and upgrades to the station had been completed (CNSC, 2001).

As part of their decision on the EA, the CNSC identified the requirement for a Follow-Up and Monitoring Program (FUMP). The FUMP was established for pre-restart and post-restart conditions to provide information on minimizing adverse effects and ensuring effective environmental protection measures were implemented (OPG, 2001). The FUMP consisted of activities to confirm before and after return to service. The implementation of the FUMP was reported in a series of annual monitoring reports provided to the CNSC.

The CNSC staff completed a comprehensive review of the FUMP reports and accepted the completion of the follow-up monitoring program in October 2008 (CNSC, 2008a).

Pickering Waste Management Facility Phase II Environmental Assessment

In 2003, prior to PWMF expanding to a Phase II site, a screening level EA was conducted to provide additional storage capacity of used fuel in dry storage containers (OPG, 2003). The scope of the project included construction and operation of Dry Storage Container (DSC) storage buildings #3 and #4.

The results of the assessment identified no significant residual adverse environmental effects of the PWMF Phase II project with the proposed mitigation measures in place. In 2004, the CNSC Secretariat concluded that the project, taking into account the appropriate mitigation measures identified in the Screening Report, was not likely to cause significant adverse environmental effects, and approved the EA (CNSC, 2004).

As part of the PWMF Phase II project, OPG submitted an Environmental Assessment follow-up monitoring program which outlined the monitoring requirements for the project (OPG, 2005a). The EA follow-up monitoring program included monitoring related to stormwater management, visual screening and public attitudes.

Stormwater drainage was monitored during the construction of DSC Storage Building #3 which included daily inspection of storm water, erosion, and the check dam. The constructor's records indicate that there were no significant problems with storm water drainage (OPG, 2010a).

To address concerns raised with respect to views of the proposed facility from the Waterfront Trail which passes by the eastern boundary of the Pickering nuclear property, original plantings along the east perimeter fence of the Pickering Nuclear site were substituted with larger, more mature trees which enhanced the screening and have better survival rates. With respect to the public attitude research survey, the results from the 2009 survey were compared to the results from the 2002 survey. The results suggest that the PWMF Phase II project did not result in a change in attitude in the local community.

Pickering B Refurbishment and Continued Operation Environmental Assessment:

As part of its planning process, OPG conducted an EA study for the PN Units 5-8 Project to refurbish one or more of the PN Units 5-8 reactors. The scope of the EA included the construction and operation of additional waste storage structures to accommodate wastes resulting from reactor refurbishment activities, and from on-going operation of the reactors.

The EA study report and nine technical supporting documents (TSDs) were submitted to the CNSC in December 2007 (OPG, 2007a). After considering the screening report, the mitigation measures, and comments filed from the public, the CNSC Commission accepted that the project would not cause significant adverse effects (CNSC, 2009).

In 2010, OPG announced that it would not proceed with refurbishing the PN units. However, OPG is proceeding with the construction of a new DSC processing building and additional waste storage structures for used fuel, namely DSC Storage Buildings #5 and #6.

No specific EA follow-up activities related to the construction and operation of additional storage buildings were identified in the PN Units 5-8 Refurbishment and Continued Operation EA.

PN Units 2 & 3 Defueled State:

The four PNGS A reactors were placed in a Guaranteed Shutdown State at the end of 1997. Following PARTS EA approval, Units 1 and 4 were returned to service. In August 2005, OPG announced that Units 2 and 3 would not be returned to service and will be placed in a Guaranteed Defueled State as part of a broader Safe Storage Program, until such time as the entire Pickering A station is decommissioned.

In 2008, a screening level EA was prepared under CEAA to place Units 2 and 3 in a Guaranteed Defueled State (OPG, 2008). Taking into account the findings of the EA including the identified mitigation measures, the proposed Guaranteed Defueled State Project will not result in any significant adverse environmental effects. The permanent removal of Units 2 and 3 from operation, and lay up of units in a guaranteed defueled, drained and dried condition, was confirmed by the CNSC in December 2008 to have no increase in risk over the existing operation (CNSC, 2008b).

1.1.2 Review of Past ERAs (1999 to 2007)

A multi-tiered EcoRA was performed from 1999 to 2002 (SENES, 1999, 2000a, 2001, 2002) to assess the overall ecological effect of operations at the Pickering Nuclear (PN) site and to support regulatory compliance. In the first phase an issue-based Environmental Review was completed in 1998 and submitted to the CNSC (then the Atomic Energy Control Board). The CNSC recommended that a screening EcoRA be performed to identify any effects the PN Generating Station has on the valued ecosystem components (VECs). A multi-tiered risk assessment was completed in response to CNSC recommendations. The Tier 1 risk assessment identified some data gaps and areas of uncertainty that were then further resolved in the Tier 2 and Tier 3 risk assessments. Although the focus of the risk assessments was on ecological receptors, some human receptors were evaluated as well. Based on the results of the Tier 1, 2, and 3 assessments, no significant ecological effects from existing chemical or radiological releases from PN were identified. The Tier 3 risk assessment recommended environmental monitoring of water and sediment in Hydro Marsh to characterize the current conditions or estimate the potential release of metal inventories from sediment back into the water column. The risk assessment also recommended some environmental monitoring including surface water, groundwater, soil, and fish to confirm assumptions and reduce uncertainty in the calculations.

In 2007 to support the Pickering B Refurbishment and Continued Operations Environmental Assessment the ecological risk assessment was updated and a human health assessment was performed (SENES, 2007a). The ecological risk assessment concluded no significant adverse effects to non-human biota due to releases of chemicals or radionuclides to the environment during existing conditions or during refurbishment and continued operations. The human health risk assessment also concluded no significant adverse effects to the public due to releases of chemicals or radionuclides to the environment during existing conditions or during refurbishment and continued operations. A follow up on site-specific risk assessment of non-potable groundwater was also conducted in 2007. No adverse effects to human health were identified based on the groundwater pathway for tritium. Additionally, to assess ecological risk a conservative assessment of a hypothetical earthworm in groundwater was assessed for tritium. The results indicated no adverse effects to ecological populations.

1.1.3 Review of 2014 ERA (2007 to 2011)

In 2014, an integrated EcoRA and HHRA was prepared to be compliant with CSA N288.6-12 guidance. The CSA N288.6-12 compliant ERA focused on monitoring data from the five-year period 2007 to 2011 (Ecometrix, 2014). The ERA identified a number of areas where supplementary monitoring studies were recommended in order to clarify risk and reduce uncertainty in future human health and ecological risk assessments. The specific recommendations and the actions taken to address the recommendations are summarized in Table 1.1. These supplementary studies were recommended as one-time studies and would only be part of the monitoring program until the objectives were achieved.

Table 1.1: Summary of 2014 ERA Recommendations and Follow-up Action Taken

2014 ERA Recommendation	Action Taken
An updated soil monitoring program on-site should be performed, focused on areas with historically elevated concentrations of tritium and a number of metals (including arsenic, cadmium, copper, lead, thallium, and zinc), to help reduce uncertainty regarding concentrations used in dose calculations for ecological receptors.	Soil sampling occurred as part of the 2015 baseline environmental sampling program.
Lake water samples should be collected along the PN U1-4 and PN U5-8 discharge channels and analyzed for hydrazine at a lower detection limit to reduce the uncertainty surrounding human exposure to hydrazine through drinking water.	Water samples were collected for hydrazine analysis in a 2014 EMP supplementary study (Ecometrix, 2015)

2014 ERA Recommendation	Action Taken
Phosphorous-32 measurements in fish (and potentially sediment) should be obtained, if possible. However, since site-specific data exists for fish and sediment, Cesium-137 should continue to be used to represent gross beta-gamma radionuclides for human dose calculations.	OPG decided not to proceed with monitoring Phosphorous-32. Effluent characterization data from PN indicated that concentrations of Phosphorous-32 in the effluent were at or below detection limits, which are lower than the dominant gamma emitters in active liquid waste, such as Cesium-137 and Cobalt-60. The likelihood of detecting Phosphorous-32 in fish is extremely low and its short half-life presents analytical limitations.
Sampling of sediment and water in the northern section of Frenchman's Bay should be performed to reduce uncertainty regarding the assessment of biota in the bay. The Frenchman's Bay wetland is located in the northern section of the bay; however, previously, biota was assessed at the mouth of the bay where sediment data were available, and where waterborne emissions from PN have the greatest impact.	Sediment and surface water sampling occurred as part of the 2015 baseline environmental sampling program.
The only exposure pathway for receptors at Hydro Marsh is through airborne deposition of tritium from atmospheric emissions from PNGS. Sampling of water at Hydro Marsh could be performed to confirm that effects from tritium deposition in the marsh are minor.	This sampling program was not completed following the 2014 ERA and the recommendation was carried forward to the 2017 ERA.

1.1.4 Review of 2017 ERA (2011 to 2015)

An ERA for the PN site, consistent with CSA N288.6-12, was completed in 2018, and focused on the 2011 to 2015 period (Ecometrix and Golder, 2018).

In order to address the recommendations from the 2014 ERA (Ecometrix, 2014), OPG undertook a number of supplementary studies in 2014 and 2015 to support the 2017 ERA. In the summer of 2014, water samples were collected for hydrazine analysis at locations near the PN discharge channels and at downstream locations (Ecometrix, 2015).

Considering the age of site environmental data and recent site alteration due to the development of Building #3 for the Pickering Waste Management Facility (PWMF), an updated baseline environmental sampling program was undertaken in 2015/2016 to reduce uncertainty in the ERA and to support future licensing activities. The baseline environmental sampling program included collection of:

1. Lake surface water data;
2. Sediment and surface water data from Frenchman's Bay;
3. Stormwater data;
4. Soil data; and
5. Noise data.

A general overview of the baseline sampling program is provided in Table 1.2. All data collected as part of the baseline sampling program are provided in Appendix F or summarized within the report as required.

Human receptors were assessed off the PN site, consistent with those assessed in the annual EMP. Radiation dose to all human receptors over the 2011 to 2015 period was well below the public regulatory dose limit of 1 mSv/a and a small percentage of natural background radiation.

No human health risks were identified due to exposure to morpholine and hydrazine.

Ecological receptors were assessed on the PN site, at the outfall, and Frenchman's Bay. Radiation dose to all ecological receptors was below the aquatic and terrestrial dose benchmark at all locations.

For non-radiological contaminants of potential concern (COPCs), the maximum concentration of copper in the outfall was above the fish and benthic invertebrate benchmarks; therefore, the hazard quotients (HQs) were above 1. However, based on the mean concentration of copper in the outfall, HQs were below the acceptable risk level of 1. Since fish are mobile, exposure to the mean concentration is more likely. Additionally, although a few benthic invertebrates may be exposed to the maximum concentration, the community as a whole is not expected to be impacted.

In Frenchman's Bay, the maximum copper concentration in water marginally exceeded the aquatic plant benchmark, and the maximum and mean copper concentrations in sediment exceeded the benthic invertebrate benchmark. The maximum iron concentration in water exceeded the benthic invertebrate benchmark, while the mean did not. The HQ exceeded 1 for aluminum and iron for a number of mammals and birds. However, exceedances of toxicity benchmarks are common in an area such as Frenchman's Bay that is highly influenced by urban runoff. PN operations contribute a small proportion of the overall risk to aquatic receptors at Frenchman's Bay.

On the PN site, in general, soils that exceeded benchmark concentrations were localized, suggesting the influence of past industrial operations rather than deposition from atmospheric sources. As such, accumulation of contaminants of potential concern in soil over time is not expected. HQs were exceeded for earthworm and terrestrial plants for a number of metals as well as petroleum hydrocarbon fraction F4. For mammals and birds, there were no exceedances of HQs based on mean soil concentrations. Sulphate levels in the ditch at the East Landfill were below effect levels.

Although site soil data from 2015 confirms localized areas of contamination, no specific monitoring or remediation was recommended in the 2017 ERA, as the contamination will be addressed during decommissioning of the PN site.

Table 1.2: Summary of Baseline Sampling Program for the 2017 ERA

Sample Medium	Location	Radiological Parameters	Non Radiological Parameters	Rationale for Monitoring
Surface Water	Lake Ontario (nearshore)	Tritium, carbon-14, cobalt-60, cesium-134, cesium-137	Hydrazine(1), alkalinity, ammonia (total and un-ionized), biochemical oxygen demand, chemical oxygen demand, hardness, pH, conductivity, temperature, total suspended solids, total residual chlorine (in-situ), petroleum hydrocarbons, morpholine, metals	To address recommendation in 2014 ERA for hydrazine at a lower detection limit to reduce the uncertainty. To update the ERA and support future ERAs and the predictive effects assessment.
Surface Water	Frenchman's Bay	Tritium, carbon-14, cobalt-60, cesium-134, cesium-137	Alkalinity, ammonia (total and un-ionized), biochemical oxygen demand, chemical oxygen demand, hardness, pH, conductivity, temperature, total suspended solids, total residual chlorine (in-situ), petroleum hydrocarbons, morpholine, metals, total organic carbon	To address recommendation in 2014 ERA.
Sediment	Frenchman's Bay	Carbon-14, cobalt-60, cesium-134, cesium-137	Particle size, total organic carbon, metals	To address recommendation in 2014 ERA.
Stormwater	PN site	Tritium, carbon-14, cobalt-60, cesium-134, cesium-137	Hardness, pH, conductivity, phosphorus, chloride, total suspended solids, petroleum hydrocarbons, metals, toxicity	To update the ERA and support future ERAs and the predictive effects assessment.
Soil	PN site	Tritium, carbon-14, cobalt-60, cesium-134, cesium-137	Polycyclic aromatic hydrocarbons, volatile organic compounds, petroleum hydrocarbons, metals and inorganics, glycol	To address recommendation in 2014 ERA to collect updated soil data.
Noise	PN site and Vicinity	Noise data		To update the ERA and support future ERAs and the predictive effects assessment.

Notes:
(1) Hydrazine was analyzed in water samples collected in 2014 as part of a supplementary study (Ecometrix, 2015).

Table 1.3 summarizes the recommendations that were presented in the 2017 ERA and subsequently made by CNSC and Environment and Climate Change Canada (ECCC). The studies undertaken to address the recommendations are incorporated into the current iteration of the ERA.

Table 1.3: Summary of Follow-up Actions from the 2017 ERA

Recommendation from the 2017 ERA	Action Taken
The only exposure pathway for receptors at Hydro Marsh is through airborne deposition of tritium from atmospheric emissions from PN. Sampling of water at Hydro Marsh could be performed to confirm that effects from tritium deposition in the marsh are minor (Ecometrix and Golder, 2018).	Sampling of water at Hydro Marsh was completed as a supplementary study and was reported in the 2016 EMP report (OPG, 2017a).
To further assess the potential for thermal effects to Round Whitefish embryos in the thermal plume over the period of continued operation of PN, it is recommended that a thermal monitoring study be conducted in the vicinity of the PN U5-8 CCW discharge to confirm the predictions made in the ERA. The monitoring should be conducted during two winter seasons (December to April). The thermal monitoring will then be incorporated into the next ERA update. Any future scientific advances in the understanding of thermal impacts on Round Whitefish embryos will be incorporated in the assessment accordingly (Ecometrix and Golder, 2018).	Thermal plume monitoring over the periods December 2018 to April 2019, and December 2019 to April 2020, were carried out by OPG and results were compared to findings in studies conducted between 2009 and 2012 (OPG, 2020b).
The expansion of PWMF Phase II will likely result in changes to the stormwater catchments in the East Complex. The appropriate stormwater outfalls in the East Complex should be reviewed and sampled accordingly to be representative of the catchment areas after the completion of PWMF Phase II expansion (Ecometrix and Golder, 2018).	This recommendation was not carried out because the PWMF Phase II expansion is still progressing. The recommendation will be carried forward to the next iteration of the ERA.
ECCC recommended that future ERA iterations use existing habitat information to estimate the percentage of warmwater fish habitat that could be affected by the discharge (OPG, 2018c).	The merits and limitations of this recommendation were discussed in a meeting between OPG, ECCC and CNSC which took place on January 31, 2022. It was agreed by all parties that the limitations outweighed the benefits and, therefore, no further analysis by OPG would be conducted.

Recommendation from the 2017 ERA	Action Taken
To address the water quality of stormwater discharging directly to Lake Ontario from the PN site, CNSC and ECCC staff recommended that OPG develop a stormwater sampling plan, and that the results be included in future ERA submissions (OPG, 2017b). During their review of the stormwater screening results presented in R000 of the 2017 ERA, ECCC noted that exceedances of aquatic benchmark values were noted at the point of discharge in Catchments 10 and 13, and Catchment 3 had 30% mortality of Rainbow Trout in 100% effluent treatment. ECCC recommended that OPG develop a plan to address the water quality of stormwater discharging directly to Lake Ontario, and also requested OPG to provide a rationale for not including other Catchments (i.e. 11, 12, 14-16A) in the stormwater assessment used to support the ERA (OPG, 2017b).	At the present time, no new stormwater sampling plans have been developed and no new studies have been conducted. OPG has indicated that updated stormwater sampling will be completed after further progression of the PWMF Phase II expansion. This recommendation will be carried forward to the next iteration of the ERA.

1.1.4.1 Tritium in Hydro Marsh Supplementary Study

In order to address a recommendation from the 2017 ERA, a supplementary study was conducted in 2016 on tritium concentrations in Hydro Marsh water, near PN. The objective of the study was to confirm that tritium concentrations at Hydro Marsh are lower than or similar to Frenchman's Bay, thereby validating the ERA's selection of Frenchman's Bay as a suitable assessment location for riparian and aquatic receptors. Water samples were collected from Hydro Marsh from April through November 2016. The analysis and frequency were the same as those used for Frenchman's Bay water samples which are part of the routine EMP.

Results of the 2016 study confirmed that there was only a minor difference in dispersion factors between Hydro Marsh and Frenchman's Bay (OPG, 2017a). Therefore, for ERA purposes, the use of Frenchman's Bay for the assessment of riparian and aquatic receptors was deemed acceptable.

1.1.4.2 2018-2020 Thermal Plume Monitoring

To further assess the potential for thermal effects to Round Whitefish (*Prosopium cylindraceum*) embryos in the thermal plume over the period of continued operation of Pickering Nuclear, the 2017 ERA recommended that a thermal monitoring study be conducted in the vicinity of the PN U5-8 CCW discharge (the PNGS B discharge channel) to confirm the ERA predictions. Based on thermal plume monitoring conducted in previous studies in the winters of 2009-10, 2010-2011 and 2011-2012 at Pickering Nuclear Generating Station (PNGS) (OPG, 2010b, 2012b, 2013a), the 2017 ERA concluded the thermal plume was not having an adverse effect on Round Whitefish embryo survival, but recommended additional monitoring. CNSC and ECCC requested two years of additional monitoring, with incorporation of the results into the next revision of the PN ERA.

The monitoring results over the periods of December 2018 to April 2019 and December 2019 to April 2020, and a comparison of these findings to the 2009-2012 studies were undertaken by OPG (OPG, 2020b).

The largest relative survival loss observed was 3.8% in 2018-2019 and 1.5% in 2019-2020, at plume locations closest to the PNGS B discharge channel. These values are well below the CNSC threshold of concern of 10% relative survival loss.

A conservative value of 7°C was chosen for plume temperature at which there could be a possible indication of acute temperature effects on Round Whitefish embryos. Eight locations had hourly water temperatures exceeding 7°C between 15-Dec-2018 and 31-Mar-2019. The longest consecutive period over 7°C during this time was 13 hours. Seven locations had hourly temperatures exceeding 7°C between 15-Dec-2019 and 31-Mar-2020, with the longest consecutive period over 7°C being 26 hours. These short-term exceedances of temperatures above 7°C are believed to have no adverse effects on the development of the Round Whitefish embryos.

Thermal monitoring conducted in the winter of 2018-2019 and 2019-2020 supported the 2018 PN ERA conclusion that there are no chronic and likely no acute adverse effects on Round Whitefish egg survival. OPG's commitment related to the additional thermal studies in support of the next iteration of the ERA has been addressed.

1.2 Goals, Objectives and Scope

The overall goals of this ERA are:

- To establish an updated baseline condition for the Pickering Nuclear site.
- To support the assessment of future shutdown and safe storage of PN.
- To update the ERA in general accordance with the CSA N288.6-12 Standard.
- To provide focus for the environmental monitoring program on relevant chemicals and radionuclides (also known as contaminants of potential concern or COPCs), media, and ecological and human receptors.

The specific objectives of this ERA, consistent with CSA N288.6-12 are:

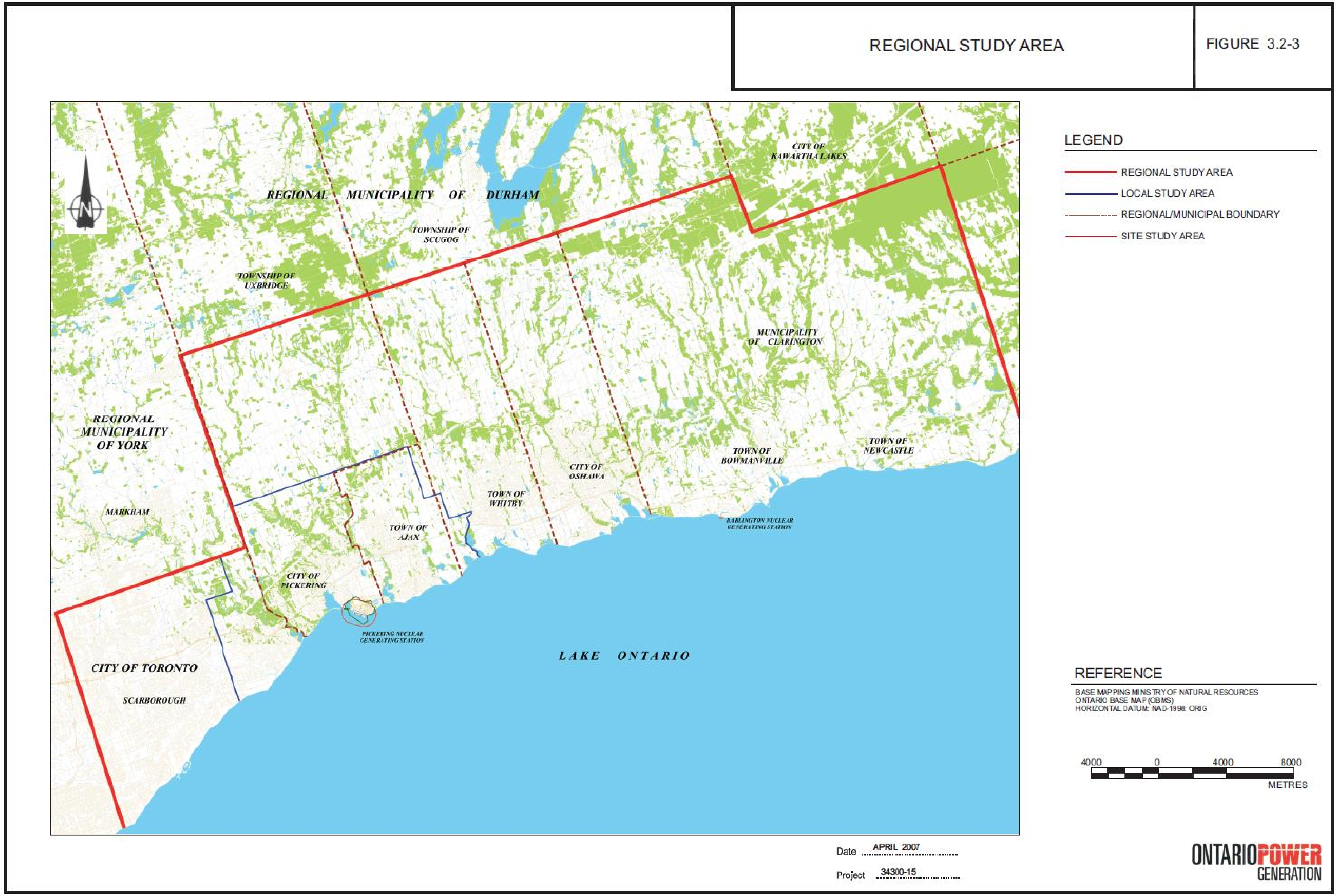
- To evaluate the risk to relevant human and ecological receptors resulting from exposure to contaminants and stressors related to the PN site and its activities.
- To recommend potential further monitoring or assessment as needed based on the results of the ERA.

The scope of the ERA encompasses normal operations at PN during the operations phase of the facility. It does not include decommissioning activities and does not address acute or high-level exposures resulting from accidents. The scope looks at the potential effects of releases from the facility on the human and ecological environment, as well as physical stressors. This ERA document provides an update to the 2017 ERA. The ERA focuses on the five-year period from 2016 to 2020 but incorporates other years of data when necessary.

Spatial boundaries define the geographical extent(s) over which likely or potential environmental effects will be considered. The spatial scale for humans includes identified human receptors (potential critical groups) within 20 km of the PN site, which is part of the local study area (LSA) and part of the regional study area (RSA), as shown on Figure 1.1. Consistent with the 2007 Pickering B Refurbishment for Continued Operation Environmental Assessment (EA), the LSA is composed of an area that extends approximately 10 km from PN. It is defined as an area which includes lands within the city of Pickering, the town of Ajax, and the eastern part of the City of Toronto (Scarborough). This study area also includes a portion of Lake Ontario abutting the property and used by those communities for activities such as recreation and community water supply and waste water discharge. The RSA extends beyond the LSA and extends approximately 20 km, to the Darlington Nuclear Generating Station in the east (i.e., the eastern boundary of the Region of Durham), to the eastern part of the City of Toronto (Scarborough) in the west, and including the municipalities in the Regional Municipality of Durham north of the PN site.

The spatial scale for ecological receptors includes receptors on-site and within the immediate site boundary and the near-field receiving waters, known as the site study area (SSA). Consistent with the 2007 Pickering B Refurbishment for Continued Operation EA, the SSA includes the facilities, buildings and infrastructure at the PN facility and the area within the 914-metre exclusion zone for the site which encompasses both land surface and part of the Lake Ontario water surface. Figure 2.17: Vegetation Communities Within and in the Vicinity of the PN Site provides the terrestrial SSA and Figure 2.19: Aquatic Site Study Area provides the aquatic SSA for ecological receptors. The aquatic SSA for ecological receptors includes the PN outfalls and Frenchman's Bay. The terrestrial SSA includes the PN site.

This risk assessment is not a probabilistic risk assessment. A probabilistic risk assessment is not required by the CSA N288.6-12 standard. Therefore, uncertainty discussions presented in this risk assessment are qualitative and semi-quantitative.



Source: (SENES, 2007b)

Figure 1.1: Local and Regional Study Area

1.3 Quality Assurance and Quality Control

The ERA makes extensive 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 Ontario Power Generation (OPG) were collected by qualified staff and analyzed by qualified performing laboratories under the 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, 2007b). Other samples such as water, sediment, soil, stormwater, and noise were collected as part of the updated baseline environmental sampling program for the PN ERA and Pickering Safe Storage Project Predictive Effects Assessment. These samples were collected and analyzed in accordance with the CSA N286-05 QA requirements for the project. Each sampling campaign involved preparation of a Sampling and Analysis Plan that outlined the data quality objectives, sampling and analysis protocol, required detection limits, roles and responsibilities, quality assurance and health and safety requirements. An inspection and test plan was completed at certain stages throughout the program to verify work was being completed as specified.

Samples collected as part of the updated baseline environmental sampling program for the PN ERA and Pickering Safe Storage Project Predictive Effects Assessment were analyzed by Maxxam Analytics (now Bureau Veritas Laboratories) and Kinectrics, which are both accredited by the Standards Council of Canada as conforming to the quality assurance requirements of International Organization for Standardization (ISO) Standard 17025.

Throughout the planning and preparation of the ERA, all Ecometrix 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.

1.4 Periodic Review of the ERA

The 2017 Pickering ERA (Ecometrix and Golder, 2018) was reviewed according to the recommendations in Clause 11 of CSA N288.6-12, for periodic review of the ERA. The results of the periodic review are summarized in Table 1.4 and expanded in the referenced sections.

Table 1.4: Summary of Results of Periodic Review of the ERA

Periodic Review Element	Results from the 2016 to 2020 Period
Changes to site ecology or surrounding land use	The 2018 review of the PN Site Specific Survey did not reveal any major changes to the surrounding area that impact assumptions for dose calculations (OPG, 2018d). Ongoing annual impingement monitoring and biodiversity monitoring at the PN site provide updated information on the aquatic and terrestrial communities, and species at risk at the PN site.
Changes to the physical facility or facility processes	A description of the physical facility and processes is provided in Section 2.2. Modifications to the facility or facility processes include: • PWMF Phase II Expansion - since 2015 one new Storage Building (SB4) was constructed, beginning on June 17, 2019 and completed in December 2020. SB4 is currently in service. A future Storage Building (SB5) is expected to be in service by December 2026. • Modifications to the Industrial Sewage Environmental Compliance Approval (ECA) in 2019 due to the collection, transmission, treatment and disposal of stormwater from the Phase II Pickering Waste Management Facility (PWMF) located in the southern portion of the property that will service a 3.8 ha drainage area. • Modifications to the Industrial Sewage ECA in 2020 to initiate chlorination in the cooling water system earlier in the season to better control mussel fouling conditions on heat exchangers. Chlorination is now based on thermal transfer efficiency data (such as trending ΔT values) instead of bioboxes. • Approval received to install from December 2020 to December 2022 a bubble curtain, tent, and piping in the nearshore Lake Ontario to mitigate algae. This is outside the timeframe of ERA assessment but should be considered for the next ERA. • Installed in October 2020 a microscrubber on Unit 4, which will redirect some of the airborne tritium to the Active Liquid Waste Tanks (ALW) for controlled release to the CCW within acceptable limits. Approval for service is expected in 2021; this is outside the timeframe of ERA assessment but should be considered for the next ERA.
New environmental monitoring data	Ongoing EMP monitoring occurred during the 2016 to 2020 monitoring period. Some supplementary studies were conducted during this period: • In 2016, tritium concentrations in Hydro Marsh water were sampled. • In 2017 the air kerma rate from the PWMF was measured. To address an ERA recommendation on thermal effects and the potential for thermal effects on Round Whitefish embryos in the thermal plume, a

Periodic Review Element	Results from the 2016 to 2020 Period
	thermal monitoring study was conducted in the vicinity of PN U5-8 CCW over two winter seasons (Dec 2018 to Apr 2019, and Dec 2019 to Apr 2020). Groundwater flow and quality is monitored under the Groundwater Monitoring Program (GWMP). No changes have occurred that would affect the next ERA.
New or previously unrecognized environmental issues	No new or previously unrecognized environmental issues have been identified.
Scientific advances	The Canadian Council of Ministers of the Environment (CCME) long-term water quality guidelines for the protection of aquatic life for manganese and zinc were updated in 2019 and 2018, respectively, as the result of new toxicology studies and new CCME assessments for these COPCs (CCME, 2018, 2019). The updated guidelines are lower (more stringent) than previously used guidelines and therefore, have potential to change existing risk implications. These new guidelines have been considered for screening of COPCs in the ecological risk assessment (see Section 4.1.3.2). In January 2021, ECCC published Version 1 of the Federal Environmental Quality Guidelines (FEQG) summary table. Since 2016, the following guidelines, applicable to this ERA, have been updated: hexavalent chromium, lead, strontium, vanadium. These new guidelines have been considered for screening of COPCs in the ecological risk assessment (see Section 4.1.3.2). In 2021, ECCC released updated Toxicity Reference Values (TRVs) for wildlife receptors (FCSAP, 2021). This document was considered during TRV selection during the ERA update with focus on new studies supporting the use of TRVs relevant to the COPCs for the EcoRA (see Section 4.3.1).
Changes in regulatory requirements	REGDOC 2.9.1, *Environmental Protection: Environmental Principles, Assessments and Protection Measures* was published in April 2017. While REGDOC 2.9.1 is a CNSC regulatory document that outlines the CNSC's approach to conducting environmental assessments, it also provides requirements and guidance for conducting ERAs. The requirement is for a facility to conduct the ERA in accordance with CSA N288.6-12. In 2020, CCME published an updated Ecological Risk Assessment Guidance Document (CCME, 2020). While not considered to be a regulatory requirement, this document is used as additional guidance to this ERA update, in addition to the CSA N288.6-12 standard.

2.0 Site Description

2.1 Site History

The PN site is in the Province of Ontario, in the Regional Municipality of Durham, 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 at latitude 43° 49′ N and longitude 79° 04′ W. The site location and vicinity are shown in Figure 2.1.

The PN Units 1-4 (U1-4) and Units 5-8 (U5-8) are located on the PN site in the City of Pickering, Ontario. They are owned and operated by OPG. They are CANada Deuterium Uranium (CANDU) pressurized heavy water generating stations with four reactor units each, commissioned according to the schedule presented in Table 2.1. PN Units 2 and 3 have been de-fuelled and are in safe storage. PN U1 and 4 and PN U5-8 have a total station net output of 1030 MWe and 2064 MWe, respectively (Golder, 2007a). Since they have been placed in service, all PN units have operated safely. In 2020, PN produced 20.5 terawatt hours (TWh) of electricity. The production performance of PN stations was 73.4% of its rated capacity (OPG, 2021c).

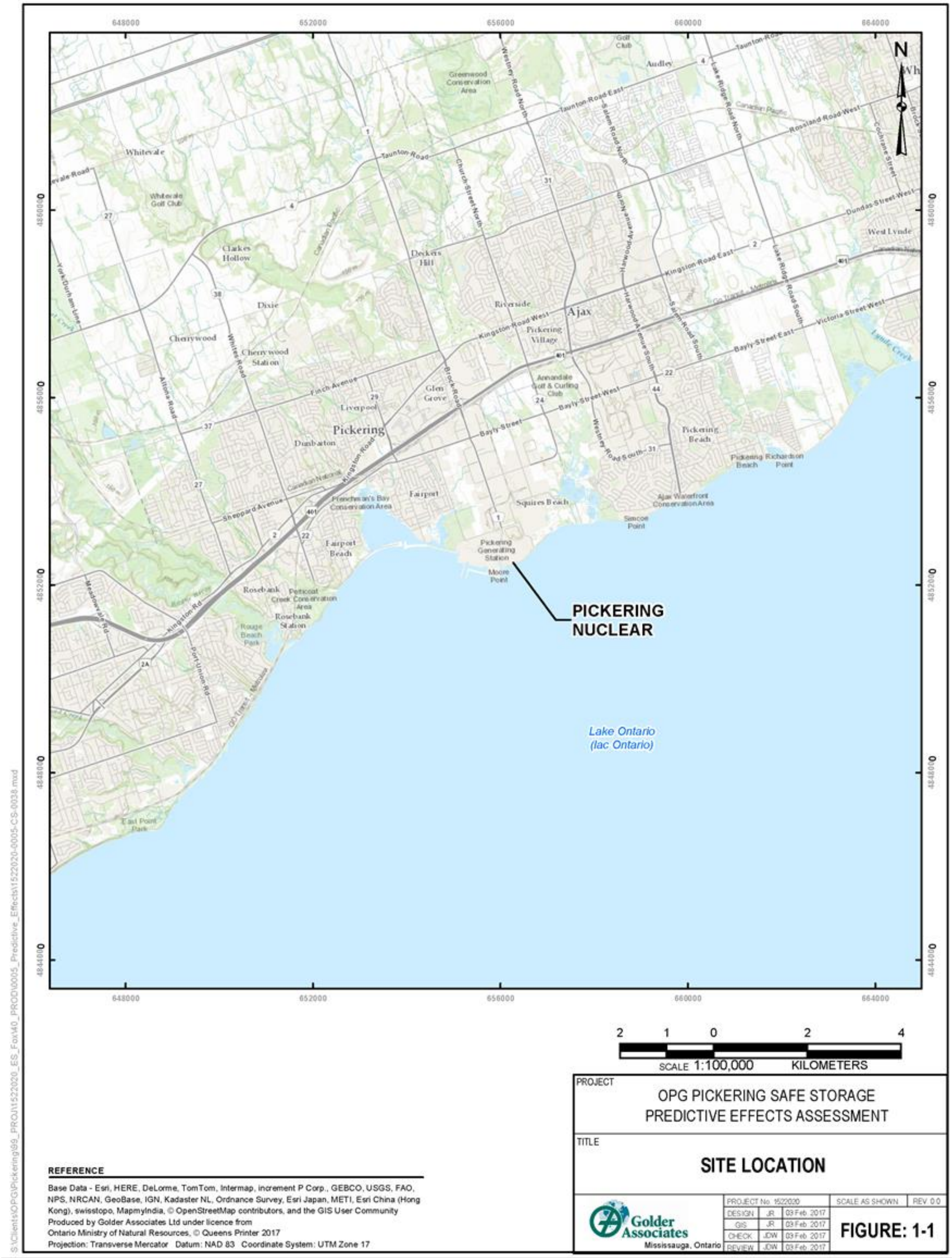
Table 2.1: In-Service Dates for PN U1-4 and U5-8

Unit #	Net Electrical Output (MWe)	In-Service Date
Pickering A		
Unit 1	515	July 29, 1971
Unit 2	0	December 30, 1971 (de-fuelled as of 2007 and are in safe storage)
Unit 3	0	June 1, 1972 (de-fuelled as of 2008 and are in safe storage)
Unit 4	515	June 17, 1973
Pickering B		
Unit 5	516	May 10, 1983
Unit 6	516	February 1, 1984
Unit 7	516	January 1, 1985
Unit 8	516	February 26, 1986

The PWMF is also located on the PN site and is comprised of 2 sites. The PWMF Phase I site is located southeast of PN Unit 8, adjacent to the east side of the station security fence, and contains two used fuel dry storage buildings and a Retube Component Storage area. 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” (OPG, 2018a). The PWMF Phase II site contains two used fuel dry storage buildings with additional buildings planned, as required. The PWMF has been commissioned according to the schedule shown in Table 2.2.

Table 2.2: In-Service Dates for PWMF Phase I and Phase II Sites

Facility	In-Service Date
PWMF Phase I Site	
Stage 1 (DSC Storage Building #1, DSC processing building)	1996
Stage 2 (DSC Storage Building #2)	2001
Retube Component Storage Area	1984
PWMF Phase II Site	
DSC Storage Building #3 and security kiosk	2009
DSC Storage Building #4 (SB4)	2020
DSC Storage Building #5 (SB5)	Scheduled for service by December 2026



Source: (Golder and Ecometrix, 2017)

Figure 2.1: PN Site Location and Vicinity

2.2 Engineered Site Facilities

An overview of each facility/operation and its releases is described in this section. Quantitative releases from the facilities/operations in both liquid and gaseous effluent are discussed in the Problem Formulation in Section 3.1.2 "Selection of Chemical, Radiological, and Other Stressors" and are presented on screening tables in Appendix A.

2.2.1 Site Overview

The PN site comprises approximately 240 hectares and accommodates eight CANDU reactors. PN U1-4 are located on the west side, and PN U5-8 are on the east side. Units 2 and 3 were defueled in 2008 and are in safe storage. Power from the generating stations is delivered to the southern Ontario electrical grid.

PN U1-4 and U5-8 share the overall PN site as well as many services and facilities. An overview of the facilities on the PN site is presented in Figure 2.4 and identifies the major facilities and structures on the PN site. The principal PN buildings and a brief discussion of their purpose are described below:

<u>Reactor buildings</u>

The reactor buildings contain the reactors, control mechanisms, fuelling machines, heat transport system, steam generators, and auxiliary equipment. For PN U5-8, an emergency control center is located to the south of each reactor building under the pressure relief duct.

- Heat is generated by the release of neutrons from fissile uranium-235 (part of the overall natural uranium fuel bundles), the moderation of the neutrons within the deuterium (heavy water) and the further release of neutrons through fission of the fuel. This critical fission reaction generates heat.
- The heat transport system circulates pressurized heavy water through the reactor fuel channels to remove the heat produced from nuclear fission. This heat is then transferred to light water in the steam generators. The chemistry of the coolant heavy water is controlled through filtering, ion exchange, and chemical addition (see Table 2.3).
- The moderator system circulates heavy water through the calandria to thermalize or slow down the neutrons to increase the probability of fission. The moderator system also includes heat exchangers to remove heat generated from the thermalization process and maintain the temperature in the calandria to approximately 60°C.
    - Twelve steam generators per reactor transfer heat from the heavy water to light water. Steam flows through the main steam piping to the turbines in the powerhouse.
- When make-up water is required in the steam and feedwater system it is supplied from the demineralized water storage tanks from the New Water Treatment Plant. Feedwater

pH and oxygen concentrations are controlled by hydrazine and morpholine addition, to limit dissolved solids and minimize corrosion. The concentration of dissolved solids in the light water is controlled by blowdown of steam generator light water (boiler blowdown).

- Each reactor building is equipped with a ventilation system which controls airflow and ambient temperatures in the accessible areas of the reactor building. Once through airflows are used to maintain a slight negative pressure in order to control the flow of air from low to high areas of contamination. All airborne emissions from the reactor buildings are controlled and monitored for radioactive contaminants by the stack monitoring system.

Reactor auxiliary bay

Each reactor auxiliary bay covers the full length of PN U1-4 and U5-8. These buildings house auxiliary systems and the irradiated fuel bays. Used fuel is initially stored in the irradiated fuel bays to allow for cooling. After this time, used fuel is transferred to DSCs and transported to the PWMF for interim storage. Filters and ion exchange columns are used to maintain optical clarity and remove radionuclides from the irradiated fuel bays while heat exchangers provide adequate cooling capability. Makeup water is provided from the demineralized water system.

Auxiliary irradiated fuel bay

The auxiliary irradiated fuel bay provides underwater storage for used fuel (spent fuel) from PN U1-4 and for cobalt-60 from PN U5-8. The auxiliary irradiated fuel bay is located to the southwest of the Unit 4 reactor building. A corridor connects the auxiliary irradiated fuel bay to the PN U1-4 irradiated fuel bay, and facilitates the transfer of spent fuel bundles from the PN U1-4 irradiated fuel bay to the auxiliary irradiated fuel bay after a minimum of four years of cooling following defueling. For PN U1-4, all transfers from wet to dry fuel storage in DSCs occur from the auxiliary irradiated fuel bay. For PN U5-8, all fuel is transferred directly from the PN U5-8 irradiated fuel bay to DSCs.

Turbine Hall and Turbine Auxiliary Bay

Each turbine hall and turbine auxiliary bay is located north of the reactor auxiliary bays and house the conventional equipment including the steam turbines, electricity generators, steam condensers, feedwater systems and much of the electrical distribution system. Each unit has a turbine/generator set with auxiliary systems. Pipes transport steam from the boilers to the turbine and have steam reject valves. The reject valves discharge steam to the atmosphere when the turbine is unavailable to accept steam.

Service Wing

The Service Wing is located in the centre of the station, between PN U1-4 and U5-8 and houses facilities common to all units. The Service Wing includes office space, change rooms, chemistry laboratories, maintenance workshops, warehouse storage space, decontamination facilities, as well as solid active waste management facilities and radioactive liquid waste management facilities.

Standby and emergency power and water systems

Standby power is available from independent gas turbine generators, located inside the protected area, in the event there is a loss of electrical power from the Ontario electrical grid and from a reactor unit. One set of six generators supplies PN U1-4 and another set of six generators supplies U5-8. The standby generators run on No. 2 fuel oil (i.e., distillate oil) that is stored just south of the generators. The fuel oil is stored within dyked areas that would contain the oil in the event of spillage or tank rupture.

Also located inside the protected area is the emergency water and power system building, located at the east end of the forebay. The emergency power system and emergency water systems contain all the necessary equipment to supply back-up power and water, respectively, following an earthquake or other emergency, including two standby generators, two oil tanks as well as water inlets and pumps.

Containment structures and pressure relief duct

The containment envelope includes the reactor buildings, the vacuum building structure, as well as the pressure relief duct (an elevated concrete structure running the length of the powerhouse which connects the reactor buildings to the vacuum building). The negative pressure containment system is an important safety feature that ensures containment of radioactive emissions if an accident scenario were to occur. The containment system is maintained at less than atmospheric pressure to ensure the flow of air is maintained into the system, thereby avoiding any release to the environment.

East Annex building

Located to the east of PN U5-8, this building is a two-story steel frame building used for the storage of new fuel, service equipment, and tooling.

West Annex building

Located to the west of PN U1-4, this building is a two-story steel frame building originally constructed to support a large-scale fuel channel replacement program for PN U1-4. This building supports fuel channel inspection, environmental qualifications and lay-up support personnel.

Electrical transmission facilities

Each unit generator has one main output transformer which steps up the voltage from the generator to the level required to deliver it to the bulk electrical power system via the switchyard. The switchyard and transmission lines are owned and maintained by Hydro One Inc.

In addition to the main output transformer, each unit also has two step-down transformers housed in the same building. The station service transformer allows electricity to be drawn directly from the grid and the generating service transformer allows generated power to be directed back to the station to meet internal needs. During normal operation, the load of the electrical distribution system is divided equally between the generating service transformer and the station service transformer.

Sediment suction system pumphouse

The sediment suction system pumphouse serves to limit the accumulation of sediment in plant systems. Large pumps from within this pumphouse move the sediment laden water to the PN U5-8 outfall. This sediment laden water mixes with the CCW prior to discharge to the lake.

Oil and chemical storage building

The oil and chemical storage building provides storage and dispensing facilities for bulk oils and combustible, toxic, corrosive, and reactive chemicals. The building is located between the PN U5-8 powerhouse and the switchyard.

Standby boiler

An auxiliary steam boiler is housed in an enclosure just south of Unit 8. The purpose of the boiler is to provide a backup supply of heating steam for the PN site. The boiler is fueled with fuel oil which is stored in a tank outside of the enclosure.

Administration, Engineering Services, and Security buildings

The administration building (located inside the protected area) and engineering services buildings (located outside the protected area) provide office space and support services for station staff.

There are two security buildings located on the perimeter security fence which monitor and control access to the protected area. The Main Security Building, located to the north of the administration building, serves as the primary access point for personnel to the protected area, while the Auxiliary Security Building, located at the east end of the site, serves as an alternate entry point for personnel and also allows access for vehicular traffic for the site.

Screenhouses, forebay, intake channel, intake and discharge ducts

The screenhouses and intake ducts draw condenser cooling water (CCW) and service water from the forebay for the PN units. A pair of rock groynes extends out into the lake to reduce recirculation of effluent water and silting. The screenhouse consists of screens to remove algae, fish, and other debris from the water. After the water is used in the condensers the CCW is discharged into covered ducts north of the powerhouse and returned to the lake via the discharge channel. Two CCW pumps per reactor pump water to the condensers.

High pressure emergency coolant injection facilities

The high pressure emergency coolant injection system is a special safety system that consists of a 780 m^3 elevated water storage tank, a pumphouse with high pressure pumps, and an auxiliary services building. The high pressure emergency coolant injection system remains poised during normal operations, ready to inject light water into the heat transport system should an accident occur that requires additional cooling of the fuel. These facilities can serve all units in a loss of coolant situation.

New Water Treatment Plant (NWTP)

The NWTP was commissioned in 2001. The NWTP has replaced the Old Water Treatment Plant which has been decommissioned. The NWTP demineralizes lake water prior to use in feedwater and other water systems requiring demineralized water at PN. The NWTP uses filters, ultra-violet sterilization, reverse osmosis, and ion-exchange columns with a design flow rate of 66 L/s. The NWTP is located north of the PN U5-8 CCW discharge and outfall, outside the Security Protected Area, and is operated under a commercial supply contract.

Heavy water upgrading plant and towers

The heavy water upgrading plant and towers upgrade heavy water from the moderator and heat transport systems. There are two separate upgrading facilities on the PN site that serve all units. The Sulzer towers, located south of Service Wing, upgrade the moderator water (number 85 and 86 on Figure 2.4). The Upgrading Plant Pickering (UPP), located northwest of Unit 4, upgrades heat transport water. In addition to the upgrading towers, the UPP facility also houses a number of heavy water storage tanks. The UPP is partially operational - Heavy Water Upgrading towers 14B (on Figure 2.4) are no longer operational, while towers and buildings 14A, C, and D (on Figure 2.4) remain operational.

Pickering Nuclear Information Centre

The Pickering Nuclear Information Centre provides informational exhibits relating to electricity generation and use with a focus on nuclear power and the environment. It is located outside of the security fence.

East Complex

The East Complex is an area consisting of several different types of operations. Included in the East Complex are technical and field support offices, warehousing, maintenance garages, machine shops, a chemical storage building, parking areas, material storage, the Auxiliary Power System, access roads, and drainage ditches. At the east end of the East Complex is the Southeast Inert Fill Area and a wetland. The Auxiliary Power System is an emergency standby power source, located in the East Complex, consisting of combustion turbine units and associated equipment (transformers, auxiliary equipment, fuel oil tanks, etc.). The system supplies electrical power to the PN site in the event of a loss of power supply from the Ontario electrical grid. The combustion-turbine standby power system uses fuel oil that is stored on-site in storage tanks within dyked areas to contain oil in case of spillage or tank rupture.

Pickering Waste Management Facility (PWMF)

The PWMF is composed of two sites, PWMF Phase I and PWMF Phase II, as shown on Figure 2.2.

The PWMF Phase I site is located within the PN Generating Station protected area and is used for dry storage of used nuclear fuel. The PWMF Phase I site consists of a Dry Storage Container (DSC) processing building, two storage buildings to store DSCs (Storage Building # 1 and #2), and an area for the Dry Storage Modules (DSMs).

The PWMF Phase II site consists of an area 500 m north-east of the site in the East Complex, within a distinct facility fenceline. PWMF II consists of a security kiosk and two Storage Buildings (#3 and #4). Storage Building #4 was recently completed in December 2020. PMWF II has an EA approved area for future expansion to include a DSC Processing Building, and Storage Buildings #5 and #6, under a separate project. Storage Building #5 is expected to be in service by December 2026.

The storage buildings at both PWMF I and PWMF II are designed to store DSCs which contain nuclear used fuel from PN U1-4 and PN U5-8. Since 1996, used fuel that has been cooled in the irradiated fuel bays has been routinely transferred to DSCs for dry storage. The DSMs, which are large cylindrical casks made of reinforced concrete and thick carbon steel inner and outer liners, store the used reactor components removed during the retubing of the PNGS A reactors in the 1980s. The DSMs are stored outdoors to the south of the PWMF Phase I site (OPG, 2018a).

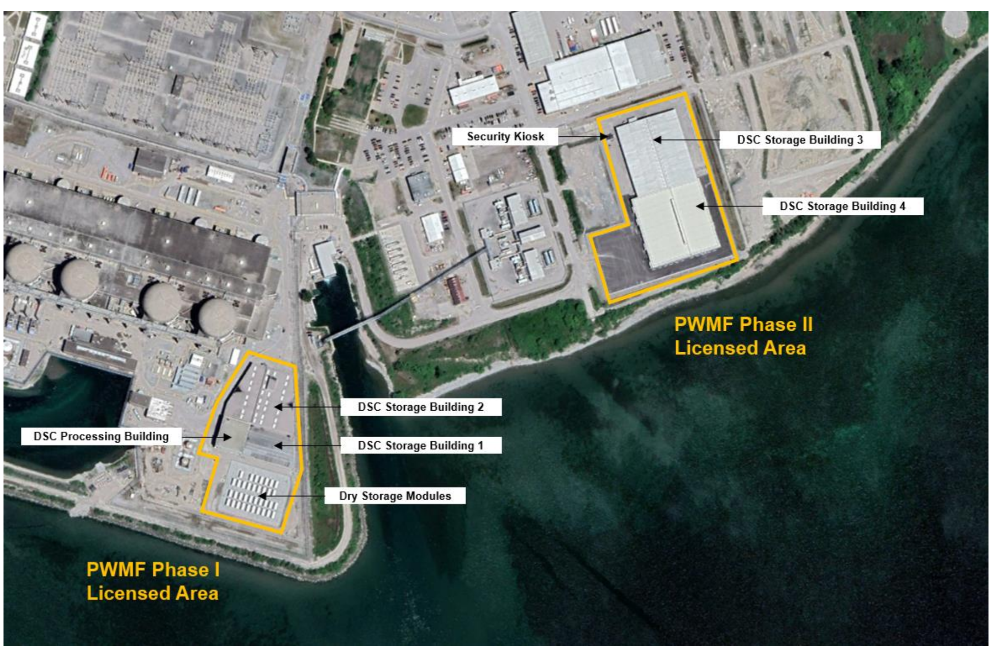


Figure 2.2: Pickering Waste Management Facility Layout

East Landfill

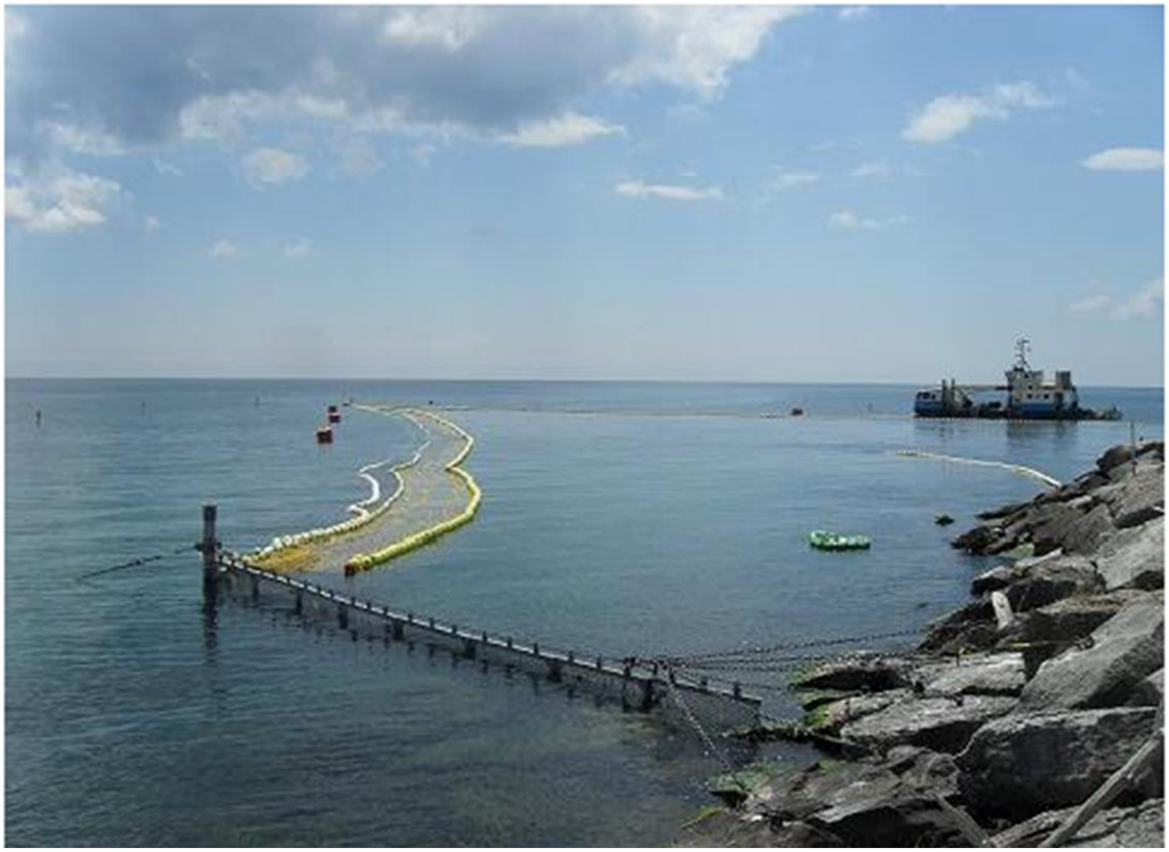
The East Landfill is an on-site waste disposal site established in 1971 to receive excavation and construction waste during the construction of PN U5-8. The landfill is located at the south-east corner of the intersection of Brock Road and Montgomery Park Road within PN's property boundary. A smaller area containing small mounds of inert fill and a wetland is located south-east of the main landfill. This 12-hectare landfill site was closed in 1988 and the East Landfill Perpetual Care Program was subsequently established in 1996 to monitor the surface water runoff quality from the East Landfill and the inert mounds of fill southeast of the main landfill (OPG, 2013b).

West Landfill

The West Landfill is located on a 1.2 hectare lot, bordered by Alex Robertson Community Park to the north, PN U1-4 to the east, Hydro Marsh/Krosno Creek to the west, and Lake Ontario approximately 45m to the south. The landfill was used for the disposal of sludges from the PN water treatment plant, including resins and PN U5-8 water intake dredgate; as well as construction debris including asphalt, gravel, concrete and metal scrap (SENES, 2007b). Groundwater from the West Landfill flows primarily outwards towards the west, south and east. Groundwater samples collected within and around the West Landfill around the time of closure did not exceed the Ontario Ministry of Environment and Energy (MOEE) Table B groundwater standards for non-potable groundwater use (MOEE, 1997).

Fish Diversion System

In 2008 the Canadian Nuclear Safety Commission (CNSC) issued a directive to PN to reduce fish impingement by 80% and entrainment by 60%. A fish diversion system (FDS) consisting of a barrier net surrounding the intake structure of PN was installed in 2009, as shown in Figure 2.3. The FDS is seasonally installed by May 1st of each year and remains functioning and in place until November 1st, in accordance with the Fisheries Act Authorization for the PN site.



Source: (OPG, 2012a)

Figure 2.3: Photo of Installed Fish Diversion System from the East Side Looking West

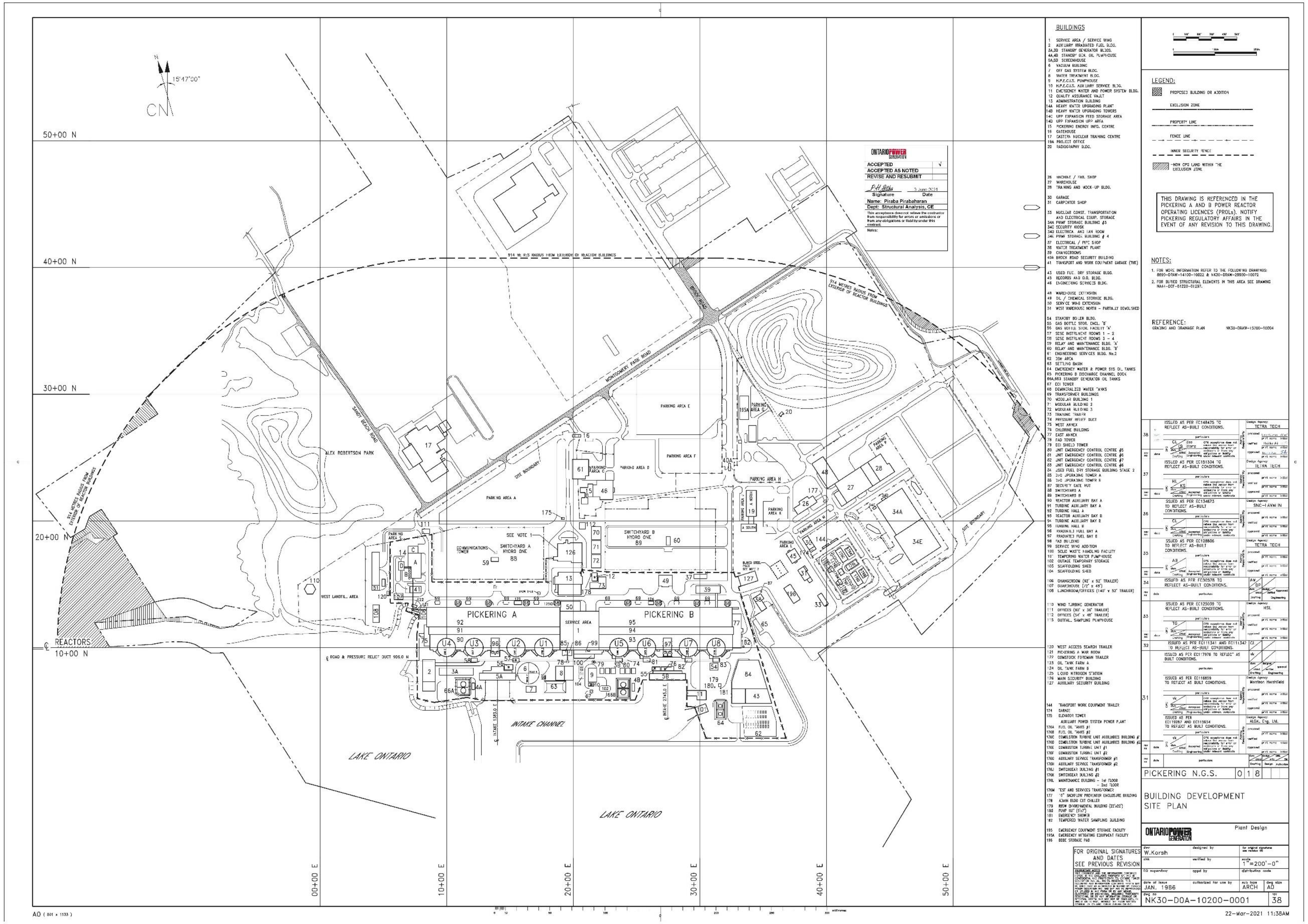


Figure 2.4: Pickering Nuclear Generation Station Site Plan

2.2.1.1 Site Drainage and Waterborne Discharges

The site water balance is presented in Figure 2.5, which is modified from (Golder, 2007a). The water balance includes a number of the water systems across the PN site including the inactive drainage system, active drainage system, domestic sewage system, stormwater system, service water, the condenser cooling water systems, and the PWMF drainage system.

Inactive drainage system

The inactive drainage system consists of a network of drains (including floor, equipment, roof and foundation drains), as well as sumps, pumps and piping which collect normally inactive liquid waste from conventional systems across the site. The main sources of inactive drainage are from floor and utility drains from the turbine hall and turbine auxiliary bay (including the foundation drains) which are collected in the inactive drainage sumps located in the basement of the turbine auxiliary bay. There are eight inactive drainage sumps in total, one associated with each unit. The inactive drainage sumps are pumped to a common inactive drainage header which is sampled as it passes through the old water treatment plant and eventually enters the yard drainage system which discharges into the forebay. In the summer months (typically June to November) when the chlorination system is in-service, the inactive drainage header is injected with sodium metabisulphite while passing through the old water treatment building. It is diverted to the settling basin prior to discharge into the forebay to facilitate de-chlorination.

Some inactive drainage streams such as overflow spray water from the ventilation system discharge directly to the CCW discharge duct.

Active drainage system

The active drainage system also consists of a series of floor and equipment drains, as well as sumps, pumps and piping, which collects normally active liquid waste, segregated according to the degree of radioactivity and chemical composition, and directs the waste to the receiving tanks of the radioactive liquid waste management system (RLWMS). Sources of the active liquid waste include reactor building floor drains, reactor auxiliary bay floor drains, irradiated fuel bay drainage, and spent ion exchange resin slurrying water. The RLWMS includes filters and ion exchange columns to purify the waste. After treatment the waste is sampled and chemically analyzed to ensure it meets radioactive and chemical limits prior to discharge. Radioactivity monitors on the discharge piping automatically stop discharge flow if the detected activity is above prescribed limits.

Service Water and Condenser Cooling Water Systems

There is a common intake for both PN U1-4 and U5-8, called the forebay. From the forebay, water is directed through either screenhouse (located at either end of the forebay) to the PN U1-4 or U5-8 intake channel which spans the length of all four units. Cooling water is pumped into each unit from the intake channel via the CCW and service water pumps. Service water is then discharged to the outfalls via the reactor building service water return (located to the south of the reactor buildings) while the CCW flows are discharged to the outfalls via the CCW discharge duct located to the north of the powerhouse. With all six units operating, total inflows/outflows for the station range on average from 190 to 220 m^3/s. CCW flows make up the largest proportion of the station inflows/outflows with a combined flow of approximately 170 m^3/s (50 m^3/s on the PN U1-4 side and 120 m^3/s on the U5-8 side).

Domestic Sewage system

Domestic sewage is collected throughout PN and is discharged into the Regional Municipality of Durham sewage mains. Sewage waste is sampled and analyzed on a regular basis for radioactivity (tritium and gross beta).

Station stormwater drainage

Stormwater is discharged directly to Lake Ontario at different locations. The switchyard drainage system directs stormwater to catchment basins and discharges it via the CCW outfall to Lake Ontario. Measures such as good housekeeping, drain covers in areas of potential oil contamination and use of swales and ditches all contribute to minimizing contamination of stormwater.

PWMF drainage

Surface drainage from the PWMF Phase I site is part of a smaller drainage basin which includes the PN U5-8 standby generators in a 3.7 ha area. Runoff from this area is directed through the PNGS drainage network and into the PN U5-8 discharge channel. Drainage from the Retube Component Storage area is also directed via catch basins to the PN U5-8 discharge channel (OPG, 2018a).

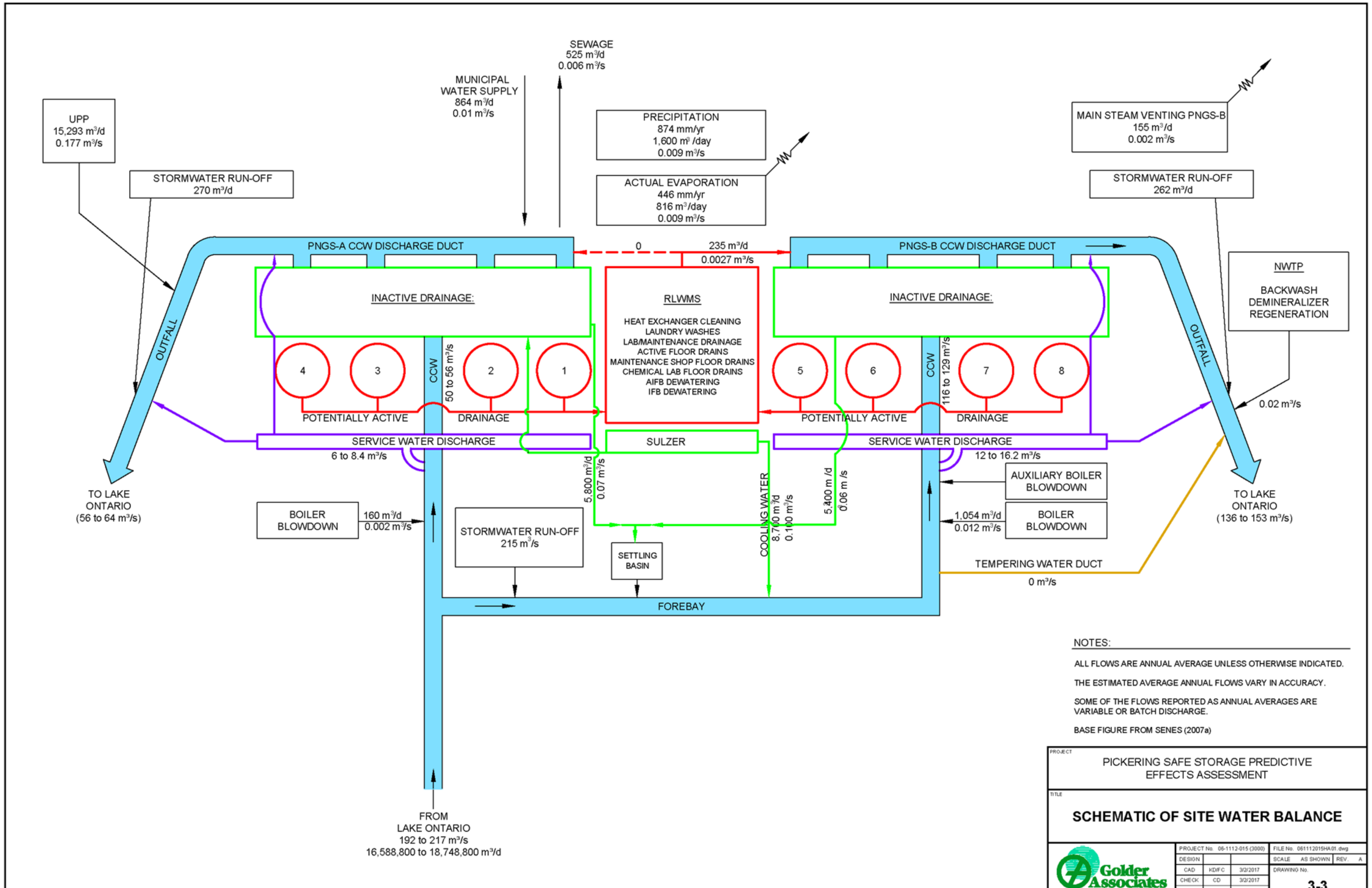
Active drainage generated from activities at the PWMF Phase I site is directed to two underground active liquid sumps and transferred via sump pumps to two holding tanks located in the Phase I workshop. Active drainage in the Phase I workshop consists of air conditioning condensate, wash water from janitorial activities, or precipitation ingress during DSC transfers that collects in the DSC processing building floor drains. The DSCs are fully drained and vacuum dried after loading at the station Irradiated Fuel Bays, and the elastomeric seals and drain plugs are present during transfer to the PWMF. The DSCs are also decontaminated prior to their transfer from the Irradiated Fuel Bays to the waste management facilities. Spot decontamination operations, which may be carried out in the DSC processing building, are not expected to generate liquids. The contents of the tanks are transferred periodically via underground piping to the RLWMS for processing.

Surface drainage from the PWMF Phase II site in the East Complex area drains to Lake Ontario via a network of storm sewers servicing Storage Buildings #3 and #4 which are approved under Amended ECA Number 0590-BEDKHH, issued August 9, 2019. The stormwater is directed to two stormceptors before being discharged to Lake Ontario.

There are no provisions for active drainage within DSC Storage Building 3. Inactive drainage beneath DSC Storage Building 3 is routed to a collection sump and can be monitored and/or discharged to the sewer system (OPG, 2018a).

<u>Other discharges</u>

Other, relatively minor sources of water discharge include periodic boiler blowdown (discharged to the intake channel), UPP discharge to the Unit 1-4 discharge channel, and the new water treatment plant discarding backwash water to the Unit 5-8 discharge channel.



Source: (Golder and Ecometrix, 2017)

Figure 2.5: Pickering Nuclear Site Water Balance

2.2.1.2 Heating and Ventilation

The heating systems are designed to provide comfort to individuals working in the plant and to maintain equipment. Ventilation and air conditioning systems control temperature, moisture, and atmospheric conditions as required for employees and plant equipment. Exhaust from areas that may contain radioactive materials are filtered and monitored prior to discharge.

The current powerhouse heating system supplies downgraded steam diverted from the steam turbine extraction to the extraction steam header which runs the length of the powerhouse. This header provides steam for building heating to powerhouse structures including the reactor auxiliary bays, turbine auxiliary bay, turbine halls, Service Wing, Administration Building, East and West Annexes and heavy water upgrading buildings.

Commercial electric heaters and/or HVAC units provide additional heating and ventilation for buildings outside of the powerhouse, including the PWMF, screenhouses, and the security buildings. Hot water from the domestic water system is used for humidification.

2.2.2 Materials Management

The PN site has a multitude of systems that are designed to manage both radioactive and non-radioactive materials. The main radioactive material managed at the PN site is heavy water.

The heavy water management system is used to store, transfer and recover heavy water for use in the heat transport system and moderator systems. The system is made up of D_2O storage tanks and collection tanks as well as pumps and piping systems to facilitate transfer between systems and units. Heavy water leakage is collected in the liquid and vapour forms and recovered for reuse.

Additional heavy water management systems include D_2O clean-up and upgrading. Clean-up processes remove impurities from heavy water using ion exchange, filtration, and oil/water separation, while the upgrading process uses distillation to separate light water from the heavy water.

A brief summary of the use(s) and the associated management methods for chemicals used across the site is presented in Table 2.3, as reported in the PNGS Hazardous Substances inventory (OPG, 2021d).

Table 2.3: Chemical Usage and Disposal

Chemical	Use	Disposal
Boric acid	Reactivity control in the moderator system	Removed by ion exchange in the moderator purification system. For disposal, see Ion exchange resins, below.
Gadolinium nitrate	Reactivity control in the moderator system	Removed by ion exchange in the moderator purification system. For disposal, see Ion exchange resins, below.
Helium gas	A cover gas preventing the ingress of air for the moderator, liquid zone controllers, and the heavy water storage tank.	Periodically purged to reactor building exhaust
Oxygen gas	Added to combine with deuterium gas to maintain pressure	Consumed and emitted with building exhaust
Hydrogen gas	Added to remove oxygen gas from the heat transport system (HTS) and to cool generators	Consumed in the HTS and vented to the reactor building exhaust. Vented to the atmosphere from the main generators
Hydrazine (35% solution)	Removes oxygen and used for pH control in the emergency coolant injection system, boiler feedwater, condensate feedwater, recirculating cooling water system, and end shield cooling water.	Consumed, but residual may be discharged to the atmosphere or to the lake. A breakdown product in the feed water is ammonia.
Lithium hydroxide	Controls pH in the HTS, end shield cooling system, and the recirculating cooling water system.	Consumed when pH is corrected.
Ion exchange resins: Neutral & Lithiated Mixed Bed Resin	Used for pH control and removal of impurities in the moderator system, irradiated fuel bay, auxiliary fuel bay, liquid zone control, heat transport system, end shield cooling system, and the recirculating cooling water system.	The resin is temporarily held within spent resin tanks and is placed in interim storage at the Western Waste Management Facility (WWMF) at the Bruce site.
Ion exchange resin: Deoxygenating Resin	Removes oxygen gas in the stator cooling water system.	Disposed as waste by licensed contractors based on analysis.
Ion exchange resin: Cation	Removal of cations in moderator (PB only)	Industrial waste disposal
Sodium metabisulphite 38% aqueous	Used in production of demineralized water and to de-chlorinate effluent.	Consumed during usage.
Descalant	Adsorbent material used as moisture remover in system driers.	Dispose as conventional waste or active waste if active – take to appropriate chem. Waste

Chemical	Use	Disposal
		drop off area as per HIS/SDS 1440
Sodium hypochlorite 7%	Used in production of demineralized water and zebra mussel control in the low pressure service water.	Consumed during usage in demineralized water production. When applied for zebra mussel control, it is consumed and the residual is discharged to Lake Ontario.
Sodium hydroxide	Used for alkalization in stator cooling water system.	Consumed during usage.
Carbon dioxide gas	Used in the annulus gas system as a carrier gas and in the generators as a purging gas	Vented from the annulus gas system to the reactor building exhaust and vented to the atmosphere from the generators.
Morpholine (45% liquid, 50% drum)	pH and corrosion control in the boiler feedwater and in the condensate feedwater	Partly consumed in its usage and the balance is lost to atmospheric discharge and boiler blowdown
Sulphur hexafluoride	Leak detection in the CCW system.	Released to Lake Ontario in small volumes
Grade B#2 oil (litres)	Fuel in the standby generator, emergency power generators.	Consumed and results in waste gases including CO_2, NO_x, SO_2, etc.
Lubricating oil and seal oil	Lubrication and sealing of the turbine system and the generator system	Reused and removed by licensed contractor.
Insulating oil	Transformer cooling in the main output and service transformers.	Removed by licensed contractor.
Ethylene glycol	Chillers in various systems.	Ethylene glycol is removed by licensed contractors.
Reolube Turbo fluid 46	Hydraulic fluid for turbine governor valves in the turbine governors.	Reused or placed into drums for disposal by licensed contractors.
Diesel (Fire pumps)	Operating diesel fire pumps	Consumed resulting in waste gases CO2, NOx, SOx, etc.
Gas, mixed, 3% nitrogen, 1.5% oxygen	QC gas – Chemical Lab use as per chemical assessment	Vented to atmosphere
Gas, freon (R22), R134A refrigerant	Used as a refrigerant for HVAC maintenance	In the system
Gas, argon, refrigerated liquid	Used in chem. Lab instrumentation. Also used by BTU as a cover gas for their metal analyzer	Return to empty gas bottle storage area and/or vendor as per HIS/SDS
Xylene	Used as solvent/thinner in various systems	Industrial waste disposal

Chemical	Use	Disposal
Refrigerant	Used as refrigerant for HVAC	Re-used in the system
Scintillant	Used for on line tritium monitors	Industrial waste disposal
Solvent, degreaser	Cleaning compound, for parts washer in different systems.	Industrial waste disposal
Xiameter PMX-561 transformer fluid	Pump motor lubricant, filling stator cavity with dielectric oil as part of overhaul	Industrial waste disposal
Teresstic B8	Lube oil for auxiliary equipment like Gear box, Compressors, Bearings- CAT ID 1007634 (replacement of Teresso 68 Cat Id 323192 for PNGS)	Industrial waste disposal
Atlas roto inject compressor fluid	Used as compressor fluid in Garage (CAT ID 323170)	Industrial waste disposal
Super fast glue flex 20-G	Adhesive for nuclear waste transportation (CAT ID 1007788)	Industrial waste disposal
Silicon spray	Lubricating door seals during loading and unloading of the package (CAT ID 1007789)	Industrial waste disposal
Kent acrysol	Paint preparation and auto body solvent for nuclear waste transportation (CAT ID 1007822)	Industrial waste disposal
Electron-22	Flushing oil to testing equipment	Industrial waste disposal
Birkosit dichtungskitt	Turbine components to prevent steam leak, sealant (CAD ID 1012768)	Industrial waste disposal
Potassium nitrate	Chem lab (CAT ID 1014997)	As per Chem Lab procedure
Scale break MP (Citric acid-based	Clean and Flush ESW Heat Exchanger coils	Industrial waste disposal
Dow 738	Lubricant, applied on generator hoses during re-assembly	Industrial waste disposal
Hellerine	Lubricant, applied on generator hoses during re-assembly	Industrial waste disposal
Loctite 243	Threadlocker, applied on generator bolts (CAT ID 848625)	Industrial waste disposal
RTV11	Silicone Injection, injected in the generator boots	Industrial waste disposal
Molykote	Electrical Insulator/Grease	Industrial waste disposal
Snoop	Sprayed on the generator hose fittings to detect leak	Industrial waste disposal
BioCorr	Rust prevention, sprayed on the generator rotor, machine ring coupling	Industrial waste disposal
Glyptal	Varnish, painted in the Stator Bore CAT ID 732194)	As per procedure
Certainty plus	Disinfectant wipe	Waste disposal

Chemical	Use	Disposal
Hand sanitizer - Formulation 3	Disinfectant	Industrial waste disposal
Neutral disinfectant cleaner	Liquid bleach, laundry-radiation protection comfo respirator routine service. CAT ID: 683051	Industrial waste disposal

2.2.2.1 Waste Management

Waste produced on-site includes used fuel, radioactive solid waste, radioactive liquid waste, radioactive gaseous waste, and non-radioactive solid, liquid, and gaseous waste.

2.2.2.1.1 Used Fuel

Historically, used fuel bundles have initially been stored in the irradiated fuel bays for at least 10 years and then transferred to DSCs for interim storage in the PWMF. In the irradiated fuel bay, used fuel bundles are placed into 96-bundle storage modules. Modules with used fuel at least 10 years or older may be loaded into a DSC, which has the capacity to hold four storage modules. The DSC is loaded with the storage modules and the lid is secured while the DSC is submerged in water. The DSC is then removed from the water, drained, the exterior decontaminated, and then the DSC is prepared for on-site transfer to the PWMF for further processing and subsequent interim storage (OPG, 2013a).

OPG is in the process of seeking approval to store 6-10 year fuel in the DSCs to free up bay space for the defueling of PN U5-8. Thermal and shielding analysis has been completed for Storage Building #3.

2.2.2.1.2 Radioactive Solid Waste

Radioactive Solid Wastes include both intermediate and low-level wastes. Low Level Waste (LLW) is defined as waste with contact radiation fields of less than 10 mSv/h at 30 cm. LLW is made of maintenance wastes from day-to-day reactor operations including cleaning materials, personal protective equipment, contaminated metal parts, metal sweepings, and miscellaneous items. LLWs are categorized as incinerable, compactable, or as non-processible.

The majority of incinerable LLW is collected in plastic bags, packed into shipping containers and transportation packages, and shipped off-site for incineration at the WWMF at the Bruce site. LLW may be briefly stored in the Solid Waste Handling Facility located in the Service Wing prior to shipping off-site.

Compactable LLW, including light gauge metals, welding rods, metal cans, insulation, metallic air filters, air hoses, small cables, and other assorted wastes, is collected in plastic bags and temporarily stored in the solid radioactive waste handling area before being shipped to the WWMF where it is compacted and stored.

Non-processible LLW includes lathe turnings and metal filings, heavy gauge metal and components, floor sweepings, glass, and larger electrical cables. This waste is packaged and shipped to the WWMF.

Intermediate Level Waste (ILW) is defined as waste with dose rates greater than 10 mSv/h at 30 cm. Materials categorized as ILW include spent ion exchange resins, disposable filters, and other non-processible radioactive wastes.

The spent ion exchange resins are slurried from the purification systems to spent resin storage tanks. Spent resin is then slurried periodically from the holding tanks to a storage (stainless steel) liner and transported in bulk de-watered form to the WWMF on the Bruce site. Low level resin/charcoal generated from the RLWMS is transferred into totes and sent to WWMF as well.

After their removal, radioactive disposable filters are placed within shielding flasks and are transferred to the in-station flask lay-down area in the PN U1-4 Turbine Loading Bay, where they are then placed within the Radioactive Filter Transportation Package and shipped to the off-site WWMF for storage.

Non-processible radioactive waste that is classified as ILW is packed in appropriate sized containers in the solid radioactive waste management area for shipment to the WWMF.

2.2.2.1.3 Radioactive Liquid Waste Management System

The RLWMS receives, treats and disposes of all potentially active liquid waste streams not containing appreciable amounts of heavy water directed to the system via the active drainage system. The activity in the liquid waste originates from contamination by mixed fission products, process system corrosion and activation products, and may include tritium, carbon-14, gross alpha and gross beta-gamma. Gross beta-gamma is a gross measure of radioactivity and is inclusive of all non-volatile radionuclides in effluent including cesium-137, cesium-134, strontium-90, cobalt-60, etc.

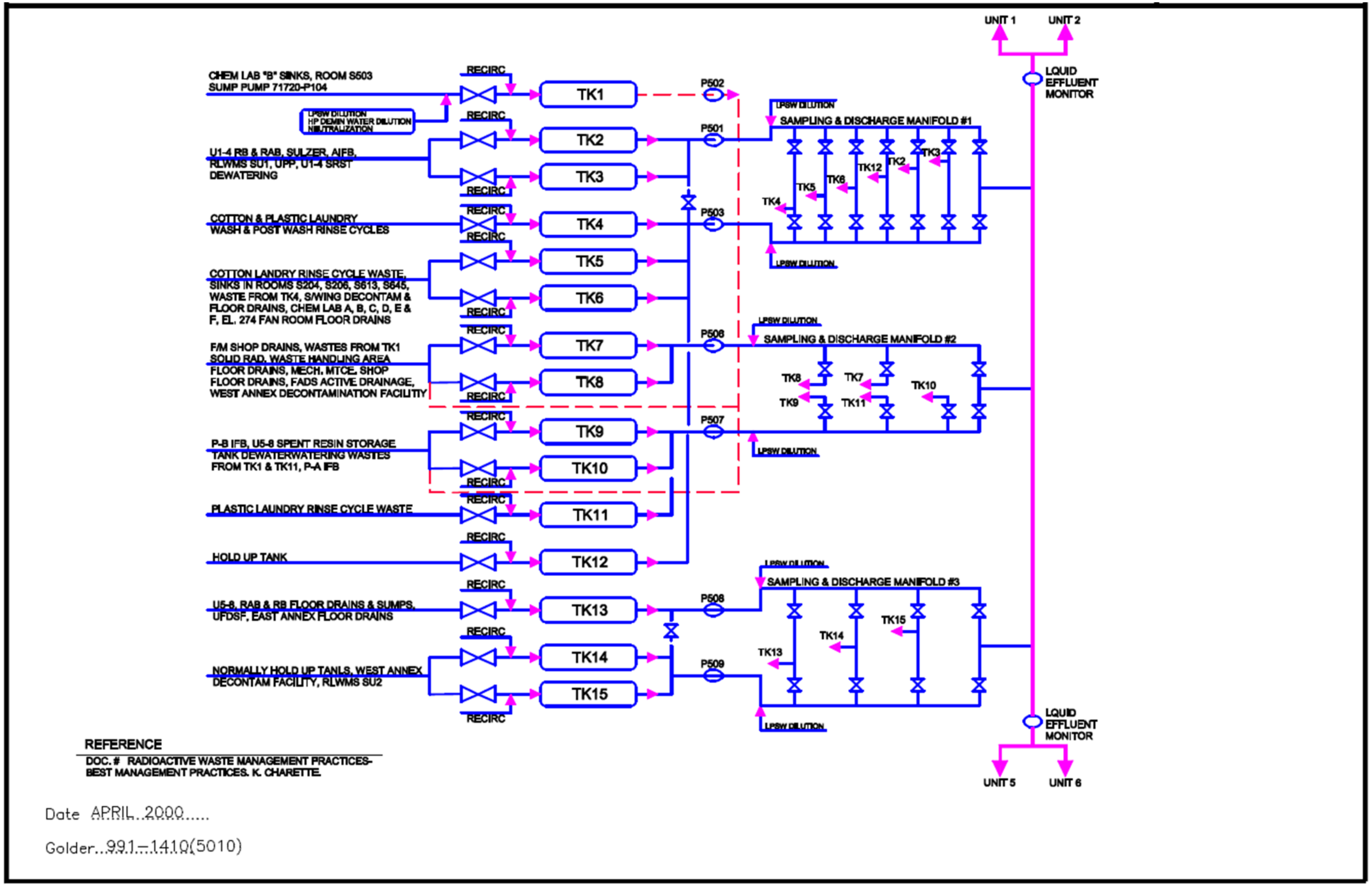
Active liquid waste from the PWMF is pumped to the RLWMS for processing. Active drainage from the PWMF consists of air conditioning condensate, wash water from janitorial activities, or precipitation ingress during DSC transfers that collects in the DSC processing building floor drains. A simplified flow diagram of the RLWMS is shown in Figure 2.6.

Active or potentially radioactive liquid wastes with chemical contaminants are directed through a purification system, as required, in order to reduce radioactive and non-radioactive impurities. Following treatment and confirmation of sample results, the waste is then directed to dedicated clean tanks where it awaits discharge. The effluent is sampled for radiological and chemical parameters prior to release and is discharged only if required specifications are met. In addition to meeting all active and non-radioactive limits, all discharges from the RLWMS must be non-toxic as directed by the Provincial Municipal Industrial Strategy for Abatement (MISA) regulations. Radioactivity monitors on the discharge piping automatically stop discharge flow if the detected activity is above specified limits. Treated wastes are discharged to Lake Ontario through the CCW discharge ducts and the PN U1-4 and U5-8 outfall structures.

The discharge limits for the RLWMS effluent are based on the assumption of at least two CCW pumps running. Radionuclides in the RLWMS effluent are monitored on a batch basis to meet the limits stated in the operating manual (for each pump):

- Carbon-14: 740 Bq/L (20 nCi/kg);
- Tritium: 4.62E6 Bq/L (125 µCi/kg); and
- Gross Beta/Gamma: 555 Bq/L (1.5E-05 µCi/mL).

Select types of non-aqueous radioactive liquids including lubricating oils and liquid scintillation cocktails are transported to the WWMF for incineration. Other non-aqueous radioactive liquids are solidified and sent to the WWMF as non-processible drummed waste. Low activity chemical wastes are collected and shipped to licensed third party facilities for treatment. Where it is necessary, secondary wastes from third party treatment, including incinerator ash, are returned to OPG for storage at the WWMF.



Source: (OPG, 2000)

Figure 2.6: Simplified Radioactive Liquid Waste Management System Flow Diagram

2.2.2.1.4 Radioactive Gaseous Emissions

Sources of airborne radioactive emissions include the air exhaust from the reactor buildings, the irradiated fuel bays, the upgraders (Sulzer and UPP), the East and West Annexes, various systems/areas within the Service Wing, and the used fuel dry storage facility (PWMF).

Tritium is released from the heavy water system to the reactor building in the form of tritiated water vapour. Tritium can also be released into the reactor building atmosphere through steam generator tube or heat transport system leaks. Dryers in the recirculating ventilation systems are used to remove airborne tritium by recovering the heavy water vapour.

Gaseous wastes from potentially active areas are monitored for radioactivity before atmospheric release. When radioactive particulates and radioiodine may be present, gases from active ventilation stacks are filtered through absolute and charcoal filters prior to release.

The primary source of particulate emissions is the heat transport system where solid radionuclides originate from within the fuel bundles or from corrosion of system components. Additional radioactive particulate emissions include cesium-137 and cobalt-60 which primarily originate from the heat transport system where they are formed in the fuel bundles or from corrosion of the system components. Carbon-14 is released from the moderator cover gas system and the annulus gas system through the reactor building stack. The ventilation exhaust stacks are monitored for particulate and gaseous carbon-14 activity where necessary.

Argon-41, a noble gas, can be released in the reactor building ventilation due to leaks and purges from the annulus gas system, moderator cover gas system, the helium sub-system of the liquid zone control system, and the calandria vault air. Xenon-133 can be released when there are minor defects in the Zircaloy-4 cladding of the fuel tubes. The radioactive noble gases cannot be effectively filtered but strict quality control in fuel elements results in low noble gas emissions. Radioactive iodine isotopes are formed by fission and can escape through defects in fuel bundles. Monitors to detect noble gas and iodine are in place where appropriate.

Up to 2018, radioactive gaseous emissions have been modelled for the purpose of public dose calculations, as two virtual sources: one from PN U1-4 and one from U5-8. Since 2019 the two sources have been combined to a single source.

2.2.2.1.5 Non-Radioactive Solid Waste

Non-radioactive wastes are re-used or recycled where feasible. Hazardous wastes are handled in accordance with regulations and are shipped off site to licensed disposal facilities. Non-hazardous solid wastes are disposed in an off-site landfill if landfill requirements are satisfied.

2.2.2.1.6 Non-Radioactive Liquid Waste

Aqueous liquid effluent, except for domestic sewage and some stormwater drainage, from PN is discharged into the CCW discharge duct, the outfall structures, or the forebay. The majority of stormwater drainage is directed to Lake Ontario, and domestic sewage is directed to the York-Durham Water Pollution Control Plant.

Non-radioactive liquid emissions are controlled in accordance with the provincial ECA requirements (formerly Certificate of Approval). Over the 2016-2020 period, OPG also operated under the MISA program under O. Reg. 215/95 (Effluent Monitoring and Effluent Limits – Electric Power Generation Sector).

OPG operates under amended ECA number 0590-BEDKHH (issued August 9, 2019), which provides approval for sewage works at the PN site including collection, transmission, treatment and disposal of wastewater, cooling water, and stormwater from the four reactor units at each of PN U1-4 and PN U5-8; and the stormwater management facility for the PWMF Phase II site. The ECA outlines effluent discharge rate objectives, and effluent concentration and temperature limits during normal operations and special events. OPG also operates under amended ECA number 9265-B9ES43 which approves sewage works associated with the New Water Treatment Plant.

The locations and concentration parameters monitored for ECA compliance during normal operations are presented on Table 2.4 (MECP, 2019a, 2019b).

Table 2.4: ECA Concentration Limits

Location	ECA Monitoring Requirements	Monitoring Frequency	ECA Limit (mg/L)
Oil/Water Separators	Oil and Grease	Quarterly	15
Inactive Drainage Effluent	Oil and Grease	Quarterly	15
	Total Residual Chlorine	Continuous (during active chlorination)	0.04
	Total Suspended Solids	Quarterly	15
PNGS-A and PNGS-B Outfall	Ammonia, unionized	Weekly	0.02
	Hydrazine	Weekly	0.1
	Morpholine	Weekly	0.02
	pH	Weekly	6.0-9.5
	Total Residual Chlorine	Continuous (during active chlorination)	0.01
Boiler Blowdown	Total Ammonia	Monthly	5
	Hydrazine	Monthly	1
	Morpholine	Monthly	50
	pH	Monthly	-
Stand-By Boiler Blowdown	Hydrazine	Daily (when in use)	0.01
	Morpholine	Daily (when in use)	2
	Unionized Ammonia	Daily (when in use)	0.02
	pH	Daily (when in use)	6.0-9.5
	Total Suspended Solids	Daily / Monthly	70 / 25

Location	ECA Monitoring Requirements	Monitoring Frequency	ECA Limit (mg/L)
New Water Treatment Plant (MISA Control Point CP 4400)	Aluminum	Daily / Monthly	13 / 4.5
	Iron	Daily / Monthly	2.5 / 1.0
	Total Residual Chlorine	Continuous	0.1
	pH	Continuous	6.0-9.5
	Toxicity –Acute	Monthly	Non-Toxic
	Toxicity – Chronic	Semi-Annual	Non-Toxic

Note:
This table is provided for reference purposes only and is a summary of information presented in Appendix B of ECA Number 0590-BEDKHH; and Tables 1 and 2 of ECA Number 9265-B9ES43. Current ECA monitoring requirements should always be verified.

Under O. Reg 215/95 PN monitors the control points in use for MISA Compliance monitoring. Monitored parameters at the control points include: aluminum, iron, pH, acute lethality/toxicity, chronic lethality/toxicity, phosphorus, oil and grease, total suspended solids, and zinc. The control points and the parameters monitored at each point are presented in Table 2.5 (OPG, 2020d). Two control points (i.e., CP 1000 Equipment Cleaning Effluent – A, and CP 3800 – Equipment Cleaning Effluent – B), have never been established and have never had discharges. In addition, control point 3600 (Oily Water Separator – A) is no longer in service. Effective July 1, 2021, the O. Reg. 215/95 has been revoked and industrial effluent monitoring and limits will be transferred to ECAs moving forward. An ECA notice was issued in 2021 to incorporate the former MISA requirements.

Table 2.5: MISA Monitoring Requirements

Control Point	MISA Monitoring Requirements	Monitoring Frequency	Daily Limit (mg/L)	Monthly Limit (mg/L)
Radioactive Liquid Waste Management System – A (CP 200) Radioactive Liquid Waste Management System – B (CP 3700)	Phosphorus	Weekly	-	1.0
	Total Suspended Solids	Daily	73.0	21.0
	Zinc	Weekly	1.0	0.5
	Iron	Weekly	9.0	3.0
	Oil and Grease	Weekly	36.0	13.0
	pH	Daily	6.0-9.5	-
	Acute Lethality/Toxicity	Quarterly	-	Non-toxic
	Chronic Lethality/Toxicity	Semi-Annually	-	Non-toxic

Control Point	MISA Monitoring Requirements	Monitoring Frequency	Daily Limit (mg/L)	Monthly Limit (mg/L)
Water Treatment Plant Neutralizing Sump[1] (CP 3100) "New" Water Treatment Plant discharge (CP 4400)	Total Suspended Solids	Daily	70.0	25.0
	Aluminum	Weekly	13.0	4.5
	Iron	Weekly	2.50	1.0
	pH	4 hours	6.0-9.5	-
	Acute Lethality/Toxicity	Quarterly	-	Non-toxic
	Chronic Lethality/Toxicity	Semi-Annually	-	Non-toxic
Oily Water Separator – A[1] (CP 3600)	pH	Daily	6.0-9.5	
	Oil and Grease	Daily	15.0	
Unit 1 Building Effluent[1] (CP 300) Unit 2 Building Effluent[1] (CP 400) Unit 3 Building Effluent[1] (CP 500) Unit 4 Building Effluent[1] (CP 600) Unit 5 Building Effluent[1] (CP 700) Unit 6 Building Effluent[1] (CP 800) Unit 7 Building Effluent[1] (CP 900) Unit 8 Building Effluent[1] (CP 100) Unit 1-8 Combined Building Effluent (CP 4600)	Total Suspended Solids	Quarterly	-	-
	Oil and Grease	Quarterly	-	-
	Acute Lethality/Toxicity	Quarterly	-	Non-toxic

Note:
[1] denotes an inactive system
[2] This table is provided for reference purposes only. MISA monitoring requirements should always be verified against O. Reg. 215/95.

In November 2018, ECCC published a notice requiring the preparation and implementation of pollution prevention (P2) plans in respect of hydrazine related to the electricity sector (ECCC, 2018). The notice applies to a facility in the electricity sector that, under normal operating conditions and at any final discharge point, has a concentration of hydrazine that is higher than 26 µg/L, if discharged to a Great Lake. Hydrazine concentrations in the PN U1-4 and PN U5-8 CCW discharges are monitored on a weekly basis. Over the period 2016-2020, the maximum weekly concentration for hydrazine was 25 µg/L (see Section 3.1.2.2.1.1), below the target levels triggering the requirement for P2 plans. Based on activities over the past five-year period OPG is not required to prepare a P2 plan for hydrazine.

2.2.2.1.7 Non-Radioactive Gaseous Emissions

Non-radioactive gaseous emissions are controlled in accordance with provincial ECA requirements. An Emissions Summary and Dispersion Modelling (ESDM) report is used to document significant contaminants that are discharged from the facility, and to maintain compliance with O. Reg. 419/05 (Air Pollution – Local Air Quality). PNGS emissions operated under Amended ECA No. 4766-A3YMB9 (issued December 2, 2015), which was replaced by Amended ECA No. 2372-BESHSC (issued October 17, 2019).

The PN site is expected to have non-radioactive gaseous emissions which primarily include products of fuel combustion, metals, and volatile organic chemicals. The 2020 ESDM lists maximum point of impingement concentrations for significant contaminants (Ortech, 2021). Contaminant concentrations are determined based on the calculated emission rates from the approved dispersion model in compliance with O. Reg. 419/05. In 2018, the model was changed from the O. Reg. 346 dispersion model to AERMOD (version 16216r).

In 2020, the ESDM report considered 131 contaminant sources at the PN site (Ortech, 2021). From this list, sources and contaminants that were considered negligible are screened out if the sources are identified to emit contaminants in negligible amounts or if the sources are insignificant relative to total emissions. Table 2.6 lists the sources and the compounds assessed from each source in 2020. Scenario 1 represents a worst-case emission scenario reflecting operations related to the production of electricity, and considers transitional operations associated with equipment start-up and shut-down. The second scenario evaluates potential additive effects to Scenario 1, as a result of routine testing and operation of emergency equipment (Ortech, 2021).

Table 2.6: Sources and Associated Contaminants in 2020

Source Identification	Source Description	General Location	Compounds Assessed in 2020
		Scenario 1	
5	Auxiliary Steam Boiler	Combustion	Nitrogen oxides, carbon dioxide, sulphur dioxide, benzo(a)pyrene, chromium VI, cobalt, fluoride, lead, nickel
7	A-Side Steam Venting System	Process Venting	Hydrazine, methylamine
8	B-Side Steam Venting System	Process Venting	Ammonia, ethanolamine, 2-(2-Aminoethoxy) Ethanol
42	Sodium Hypochlorite Storage Tanks Screen House A and B	Maintenance Facilities	Sodium hypochlorite
92	Diesel Air Compressor #1	Water Intake Channel	Nitrogen oxides, carbon dioxide, sulphur dioxide, benzo(a)pyrene
93	Diesel Air Compressor #2	Water Intake Channel	Nitrogen oxides, carbon dioxide, sulphur dioxide, benzo(a)pyrene

Source Identification	Source Description	General Location	Compounds Assessed in 2020
131	Diesel Generator for Air Dryers – Air Curtain	Water Intake Channel	Nitrogen oxides, carbon dioxide, sulphur dioxide, benzo(a)pyrene
Scenario 2			
1	Six (6) Standby Gas Turbine Generating Sets – A Side	Combustion	Nitrogen oxides
2	Six (6) Standby Gas Turbine Generating Sets – B Side	Combustion	Nitrogen oxides
5	Auxiliary Steam Boiler	Combustion	Nitrogen oxides
3a-1	Emergency Power Generators	Combustion	Nitrogen oxides
57-1	One (1) 57 MW Combustion Turbine Unit	Combustion	Nitrogen oxides
58-1	Auxiliary Diesel Generator	Combustion	Nitrogen oxides
65-2	One (1) 420 HP Diesel Powered Fire Pump	PA Screenhouse	Nitrogen oxides
92	Diesel Air Compressor #1	Water Intake Channel	Nitrogen oxides
93	Diesel Air Compressor #2	Water Intake Channel	Nitrogen oxides
131	Diesel Generator for Air Dryers – Air Curtain	Water Intake Channel	Nitrogen oxides

2.3 Description of the Natural and Physical Environment

This section will describe the natural and physical environment according to the spatial scale of the ERA, including parts of the SSA, LSA and RSA, as defined in Section 1.2.

This section will briefly describe meteorology and climate, site geology, hydrogeology, hydrology, vegetation communities, aquatic communities, human land use, and population distribution with a focus on PN site conditions. More detailed information can be obtained from the following TSDs for the Pickering B Refurbishment for Continued Operation EA with updates based on information from 2016 to 2020:

- NK30-REP-07701-00003 "Atmospheric Environment" (SENES, 2007a);
- NK30-REP-07701-00006 "Geology, Hydrogeology and Seismicity" (Golder, 2007b);
- NK30-REP-07701-00007 "Surface Water Resources" (Golder, 2007a);
- NK30-REP-07701-00008 "Aquatic Environment" (Golder, 2007c);
- NK30-REP-07701-00009 "Terrestrial Environment" (Golder, 2007d);
- NK30-REP-07701-00015 "Human Health" (SENES, 2007c); and
- NK30-REP-07701-00004 "Radiation and Radioactivity" (SENES, 2007d).

2.3.1 Meteorology and Climate

The PN site is located in southern Ontario on the north shore of Lake Ontario. It displays a humid continental climate with four distinct seasons. In Southern Ontario, the climate is highly modified by the influence of the Great Lakes which results in uniform precipitation amounts year-round, delayed spring and autumn, and moderated temperatures in winter and summer (EC, 1997). Meteorological data were collected from stations within the site, local and regional areas.

2.3.1.1 Temperature

Local air temperature data are collected at the PN meteorological station at a height of 10 metres above ground level. The local temperature data from the PN meteorological station for the five-year period including 2016 to 2020 are summarized as monthly mean, minimum and maximum values in Table 2.7. Figure 2.7 presents the monthly values for the period. Winter mean monthly temperatures, December to March, are below or close to 0°C. Summer mean monthly temperatures, June to September, are typically above 15°C. The mean annual temperature for 2016 to 2020 was 8.67°C.

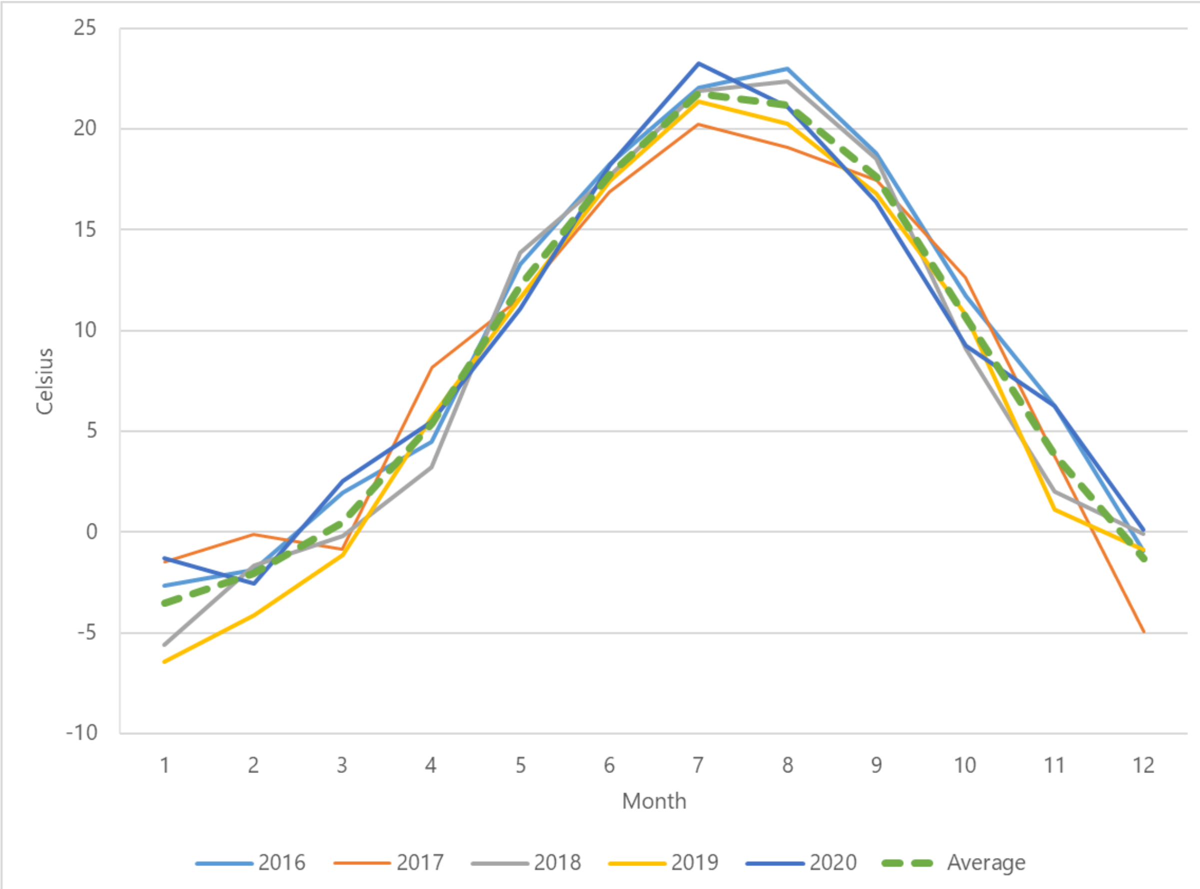


Figure 2.7 Average Monthly Air Temperatures Reported at the PN Meteorological Station (2016-2020)

Table 2.7 summarizes the most recent air temperature data available for two regional meteorological stations near the PN site: Pearson International Airport (TOR) (1981 to 2010) and Oshawa Water Pollution Control Plant (OSH) (1981 to 2010) (Government of Canada, 2021), along with temperature data from 2016 to 2020 from the PN local meteorological station (at the 10 m elevation). The local meteorological data collected from the PN meteorological station are generally consistent with the regional air temperature normals. Table 2.7 displays monthly average air temperatures and demonstrates that the highest mean air temperatures, both regionally and locally, occurred in July, and the lowest mean temperatures occurred in January. A mean daily maximum air temperature of 23.28 ºC was recorded in July and a mean daily minimum air temperature of -6.44 ºC was recorded in January at the PN site, respectively.

Table 2.7: Air Temperature Normals near Pickering Nuclear

Month	Daily Mean (°C)			Mean Daily Maximum (°C)			Mean Daily Minimum (°C)		
	TOR[1]	OSH[2]	PN[3]	TOR[1]	OSH[2]	PN[3]	TOR[1]	OSH[2]	PN[3]
January	-5.49	-4.76	-3.50	-1.51	-1.06	-1.29	-9.44	-8.45	-6.44
February	-4.54	-3.61	-2.06	-0.35	0.06	-0.12	-8.7	-7.28	-4.13
March	0.06	0.37	0.46	4.62	4.24	2.53	-4.49	-3.51	-1.11
April	7.06	6.62	5.40	12.21	10.76	8.17	1.86	2.46	3.22
May	13.12	12.3	12.29	18.79	16.89	13.84	7.41	7.68	11.10
June	18.6	17.57	17.71	24.19	22.26	18.27	12.95	12.85	16.91
July	21.45	20.55	21.77	27.06	25.13	23.28	15.79	15.93	20.26
August	20.55	19.97	21.16	26.01	24.26	22.97	15.05	15.64	19.08
September	16.2	15.94	17.59	21.61	20.16	18.82	10.75	11.69	16.37
October	9.5	9.47	10.70	14.31	13.32	12.65	4.63	5.57	9.12
November	3.72	4.21	3.89	7.59	7.38	6.28	-0.17	1.02	1.13
December	-2.18	-1.18	-1.33	1.41	2.07	0.14	-5.76	-4.43	-4.95
Year	8.17	8.12	8.67	-	-	-	-	-	-

Notes:

[1] Toronto Pearson International Airport, 1981-2010 (Government of Canada, 2021).

[2] Oshawa Water Pollution Control Plant, 1981-2010 (Government of Canada, 2021).

[3] Pickering Nuclear, 2016 to 2020 PN on-site Meteorological Station.

2.3.1.2 Precipitation

Local precipitation data are not available from the PN site. Precipitation data were obtained for the Oshawa Climate Station (43°52' N; 78°50' W), located approximately 19 km east of PN in Pickering for the period of 1981 to 2010. Climate normals for the Oshawa Climate Station for the period of 1981 to 2010 provide the most recent available precipitation data for the regional study area at this time (ECCC, 2020). Precipitation, rain and snow fall data for 1981 to 2010 are summarized in Table 2.8. The data demonstrate that precipitation is fairly consistent throughout the year with slightly more precipitation in the second half of the year. The Oshawa station reports an average total annual precipitation of approximately 871.9 mm of which less than 15% is snowfall. Total monthly precipitation averages range from approximately 54 mm in March to approximately 94 mm in September.

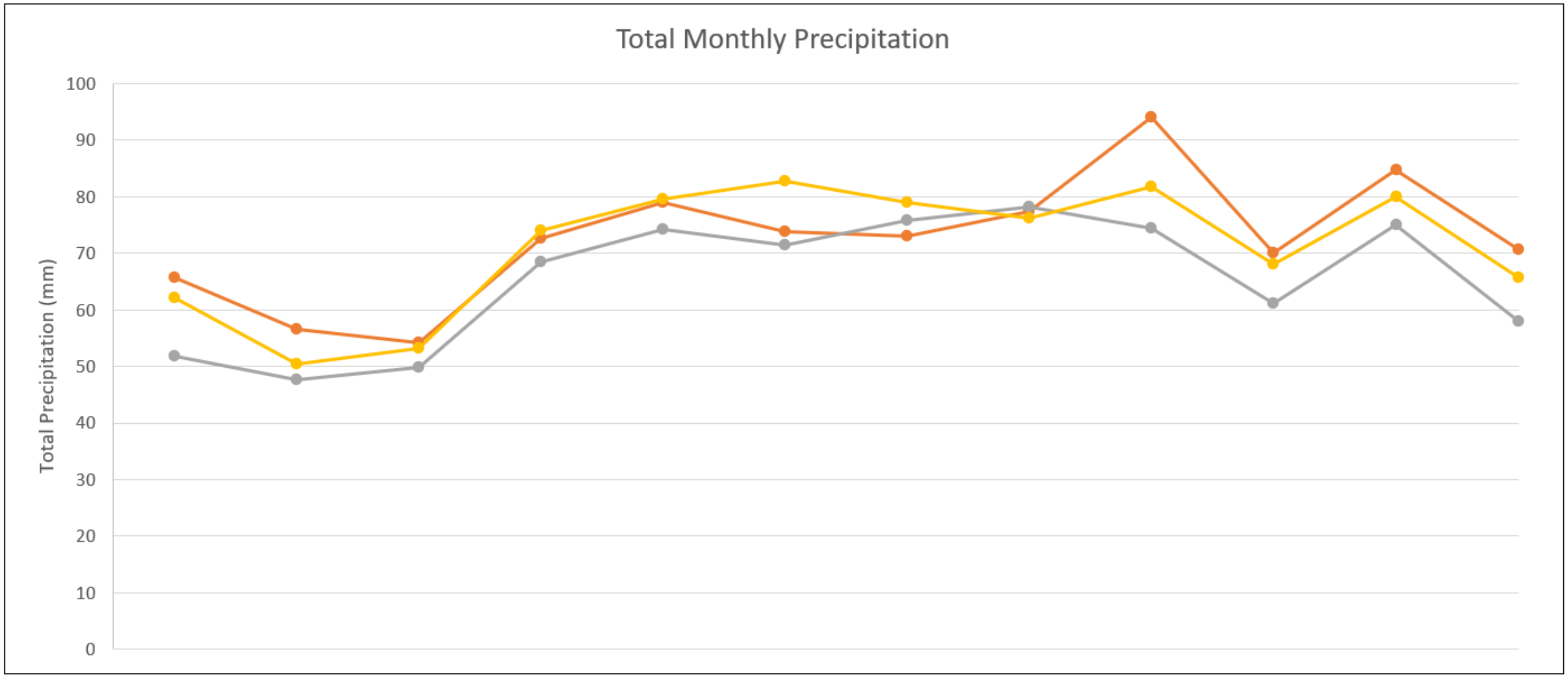
Total monthly precipitation normals from Oshawa are compared to the most recent precipitation normals (1981 to 2010), for the Pearson International Airport (TOR) and Toronto Buttonville Airport (BUT) climate stations (ECCC, 2020). The TOR is located approximately 35 km west – south – west of the PN site, and the BUT is located approximately 24 km north-west of the PN site. The data sets for these meteorological stations overlap for the period from 1981 to

2010. Table 2.8 and Figure 2.8 show that the various stations within the regional study area follow similar trends in monthly precipitation.

In the past, local precipitation data were taken from the Frenchman's Bay Climate Station, located a few kilometers west of PN in Pickering where data for the period of 1971 to 2000 were available. Based on the period of 1971 to 2000, precipitation at Frenchman's Bay was fairly consistent throughout the year with slightly more precipitation in the second half of the year. The Frenchman's Bay station reported an average annual precipitation of approximately 879 mm of which less than 15% was snowfall. Monthly precipitation averages ranged from approximately 49 mm in February to approximately 84 mm in September.

Table 2.8: Precipitation from the Oshawa Climate Station (1981-2010) (ECCC, 2020)

Month	Monthly Averages			Daily Extremes		
	Precipitation (mm)	Rain (mm)	Snow (cm)	Precipitation (mm)	Rain (mm)	Snow (cm)
January	65.6	30.0	35.6	42.6	42.6	27.9
February	56.6	31.7	24.9	42.8	42.8	27.0
March	54.2	40.7	13.5	32.8	32.8	18.4
April	72.7	70.6	2.0	47.6	47.6	20.3
May	78.9	78.9	0	41.6	41.6	0
June	73.9	73.9	0	144.8	144.8	0
July	73.1	73.1	0	70.4	70.4	0
August	77.4	77.4	0	75.4	75.4	0
September	94.0	94.0	0	80.8	80.8	0
October	70.1	70.0	0.1	45.6	45.6	6.6
November	84.8	80.0	4.7	59.0	59.0	17.8
December	70.7	45.8	24.9	39.1	35.6	29
Annual Total	871.9	766.1	105.8	-	-	-



	January	February	March	April	May	June	July	August	September	October	November	December
OSH	65.6	56.6	54.2	72.7	78.9	73.9	73.1	77.4	94.0	70.1	84.8	70.7
TOR	51.8	47.7	49.8	68.5	74.3	71.5	75.7	78.1	74.5	61.1	75.1	57.9
BUT	62.1	50.5	53.2	74.1	79.6	82.8	79.0	76.2	81.8	68.0	80.0	65.7

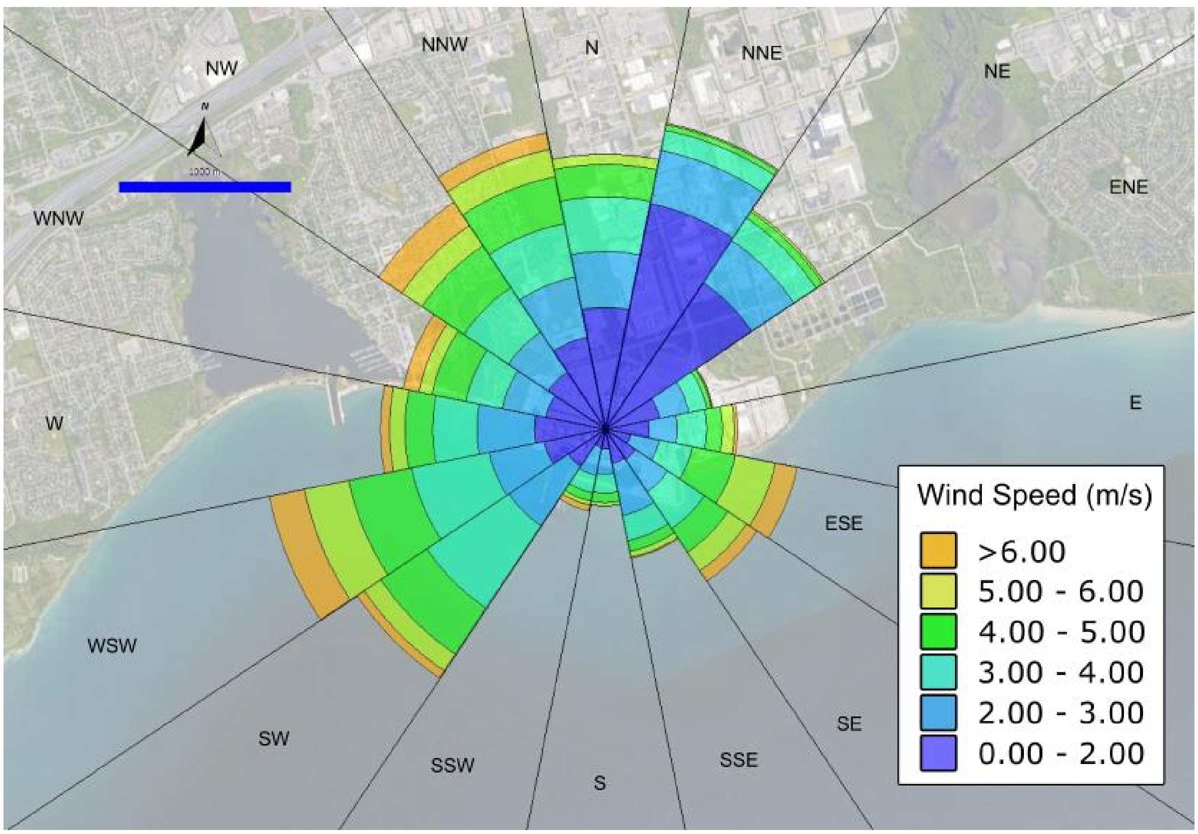
OSH – Oshawa WPCP, 1981-2010 (Government of Canada, 2021)
TOR – Toronto Pearson International Airport, 1981-2010 (Government of Canada, 2021)
BUT – Toronto Buttonville Airport, 1981-2010 (Government of Canada, 2021)

Figure 2.8: Comparison of Total Monthly Precipitation for Three Regional Meteorological Stations

2.3.1.3 Wind

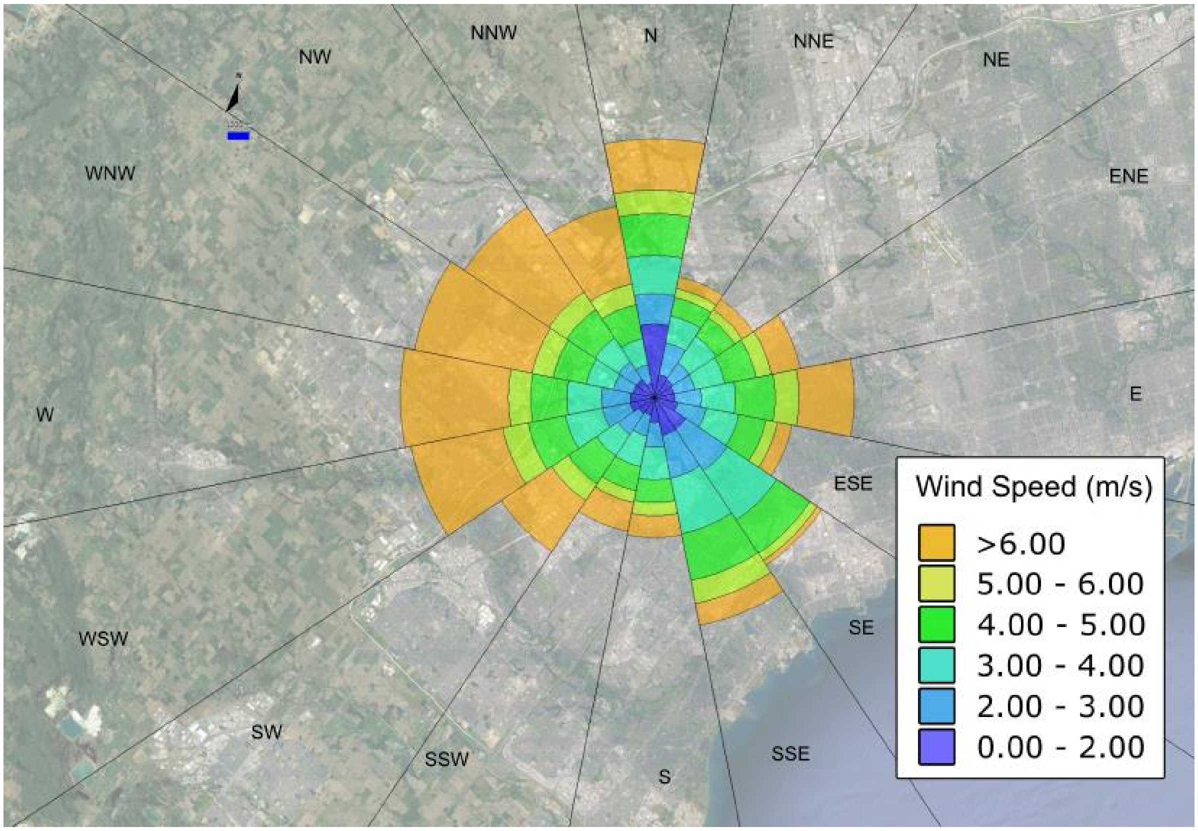
The most recent consecutive five-year period of reliable wind data is 2016 to 2020. The data are summarized as a windrose diagram in Figure 2.9 (Note: Wind is blowing from the indicated direction). The 5-year average meteorological data from 2016 to 2020 are expected to be representative of current average meteorological conditions. During this period, calm winds, less than 2 m/s, were reported approximately 36% of the time while winds with measured speeds from 2 to 3 m/s and 3 to 4 m/s were observed approximately 20% and 19% of the time, respectively.

The prevailing winds for the 2016 to 2020 period were from the northwest approximately 8.9% of the time, north-northwest 8.2% of the time, from the southwest 8.3% of the time, and from the north approximately 8.6% of the time. The distribution of winds at the PN site are slightly different from those reported for the region based on wind patterns reported at Pearson International Airport (2016 to 2020), where the wind direction is primarily from the north and the west (see Figure 2.10).



Note: Direction is where wind blows from

Figure 2.9: 2016-2020 Annual Average Windrose at 10-m Tower



Note: Direction is where wind blows from

Figure 2.10: 2016-2020 Annual Average Windrose at 10-m Tower from Pearson International Airport

2.3.2 Geology

A substantial body of information has been collected at the PN site through work carried out during previous investigations, including geological drilling investigations, monitoring well installations and sampling. These data have been summarized in the Pickering B Refurbishment EA (SENES, 2007b) and a more detailed discussion is provided in (Golder, 2007b). The following sections provide an overview of the regional and local bedrock and surficial geology, and a summary of bedrock and surficial geology for the PN site and offshore.

2.3.2.1 Bedrock

On a regional scale, the PN site is underlain by Ordovician age sedimentary rocks composed of nearly flat-lying shales and limestones that dip gently (1%) southward, characteristic of the north shore of Lake Ontario. The relatively undeformed Ordovician sequence lies unconformably upon gneiss crystalline Precambrian rocks that form the basement complex.

The bedrock beneath the site has been investigated by numerous geotechnical and hydrogeological investigations including over 500 boreholes drilled over the past 45 years

(Golder, 2007b). A cross section of the subsurface conditions beneath the PN site and offshore is presented in Figure 2.11. In general, the bedrock surface is encountered at depths of approximately 10 m to 20 m below the surface with localized areas of low bedrock topography.

The stratigraphic sequence of the Ordovician shales that underlie the PN site, in descending order, include Blue Mountain Formation shale and Whitby Formation shaly limestone and shale, which overly a thick limestone sequence. The overlying shale sequence consists of the grey fissile shale of the Blue Mountain Formation, approximately 10 to 20 m thick, and the underlying black petroliferous shale of the Whitby Formation, approximately 5 to 7 m thick. The limestone sequence is composed of the Lindsay, Verulam, Bobcaygeon and Gull River Formations. The combined limestone sequence has a thickness of approximately 180 m. Underlying the limestone sequence are clastic sediments of the comparatively thin (12 m) Shadow Lake Formation which occur on the Precambrian basement complex (Golder, 2007b).

The surface of the bedrock sequence slopes southward from elevations of 68 metres above sea level (masl) at the north of the site to elevations of approximately 47 masl approximately 1.5 km offshore in Lake Ontario as shown in Figure 2.12 (Golder, 2007b). The projected local dip of the bedrock is southeastward at a generally uniform grade of 1% (Golder, 2007b). The bedrock surface directly beneath the PN site, in the vicinity of the units is relatively level, varying between elevations of approximately 58 m to 62 m, with a gentle southward dip of approximately 0.1% to 0.2%.

2.3.2.2 Surficial Geology

The PN site is situated on the north shore of Lake Ontario between the Oak Ridges Moraine to the north and the Lake Ontario shoreline to the south. The Oak Ridges Moraine is situated approximately 20 km to 30 km inland from the north shore of Lake Ontario. It forms the regional height of land separating the Trent System and Lake Simcoe drainage to the north from Lake Ontario drainage to the south. The moraine is composed of thick deposits of glacial till and sand and gravel that are associated with hummocky terrain at the surface (Golder, 2007b). South of the moraine, the north shore of Lake Ontario is largely underlain by glacial till and glaciolacustrine deposits of clayey silt to silty clay composition. These deposits are exposed in bluffs along the lakeshore and in stream valleys throughout the area. Locally, the surficial geology predominantly comprises glacial till, or glaciolacustrine silts and clays overlying the till, which forms drumlin ridges oriented approximately northwest-southeast.

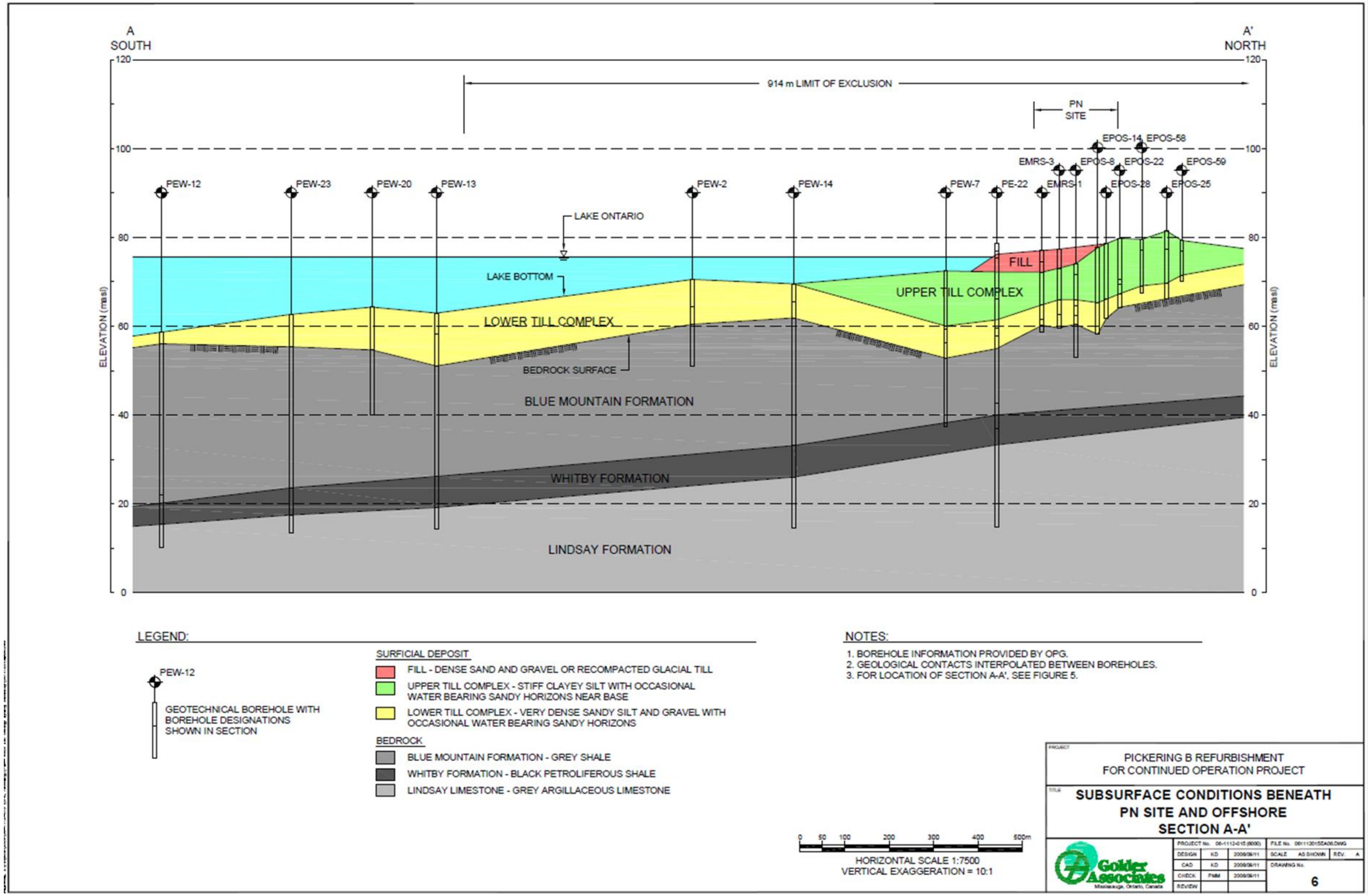
Investigations conducted in advance of the construction of PN U1-4 and U5-8 indicate that the pre-construction subsoils in the area of the existing plant generally consisted of glacial silt and sand tills up to 24 m thick overlying shale bedrock. Currently, the soil sequence overlying the bedrock beneath the PN site can be subdivided into three main layers comprising construction fill, a recent Upper Till Complex and an older Lower Till Complex overlying bedrock (Golder, 2007b) as illustrated in Figure 2.11. The elevations of the upper and lower soil complexes were found to range from about 67 masl to 79 masl, and 56 masl to 67 masl, respectively, within the main PN built area.

The fill material consists of either sand and gravel backfill that was placed for foundations, or recompacted clayey silt placed in the reclamation areas. The fill material underlies most of the PN site south of the former Lake Ontario shoreline. Structures such as the Reactor Buildings and Reactor Auxiliary Buildings were placed on 3 m to 6 m of compacted granular fill.

The Upper Till Complex forms a generally uniform blanket over a large portion of the site with a thickness that typically varies from 6 m to 15 m (Golder, 2007b). It generally consists of cohesive, soft to very stiff, moist, grey, clayey silt to silty clay, with sand and some gravel and occasional boulders; between 20% to 40% of the till is comprised of clay (Golder, 2007b). The Lower Till Complex is approximately 4 m to 12 m thick and directly overlies the shale bedrock. It generally consists of non-cohesive, very dense, grey, sandy silt to silty sand and gravel till, with a clay content of approximately 7% to 16% (Golder, 2007b). Water bearing layers and lenses of interglacial silt, sand and gravel have been encountered at the base of the upper soil complex and interbedded within the lower complex.

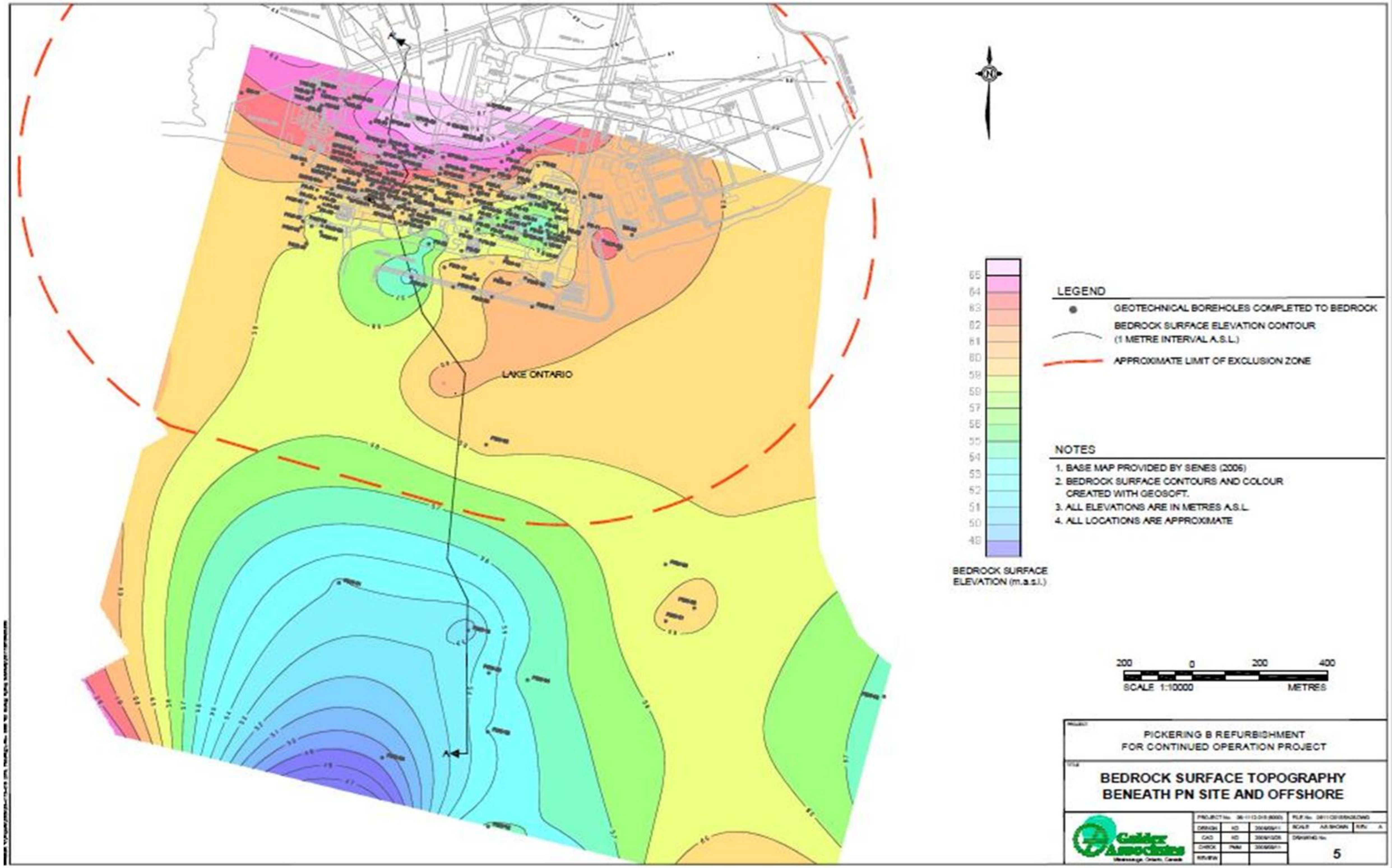
2.3.2.1 Soil Type

The soil type used in the IMPACT model is loam. This is consistent with the recommendation in CSA N288.1 to use a clay or loam soil type for Southern Ontario. Loam is considered more characteristic of topsoil properties where receptor exposures are expected to occur.



Source: (Golder, 2007b)

Figure 2.11: Subsurface Conditions Beneath the PN Site and Offshore Section A-A′



Source: (Golder, 2007b)

Figure 2.12: Bedrock Surface Topography beneath the PN Site and Offshore

2.3.3 Hydrogeology

On a regional scale, the permeable layers of sands, or sand and gravels buried within and between low permeability till deposits constitute aquifers that support groundwater flow. The tills typically have low permeability due to their fine granularity and behave as aquitards, restricting infiltration and the recharge of water to the permeable layers. The bedrock deposits of shale and limestone that underlie the surficial deposits also have low permeability, except for some weathered zones and open fractures. The exposed areas of sand and gravel within the Oak Ridges Moraine are a significant regional source of groundwater recharge from precipitation. Once recharged, the direction of groundwater flow in the buried sand and gravel deposits generally parallels that of surface streams, flowing away from the height of land formed by the moraine toward adjacent areas to the north and south. Some of the groundwater recharged in the Oak Ridges Moraine subsequently discharges into stream beds providing baseflow that maintains the streams during the dry periods of the year when there is little or no surface runoff.

The regional direction of groundwater flow south of the Oak Ridges Moraine is southward toward Lake Ontario and generally parallel to the land slope. On a local scale, groundwater flows toward one of three surface water bodies in the vicinity of the PN site, Frenchman's Bay to the west, Duffins Creek to the east and Lake Ontario to the south. Both Frenchman's Bay and Duffins Creek flow into Lake Ontario.

The results of historic site investigations and monitoring have provided an understanding of the groundwater flow system below the PN site. A hydrogeological conceptual site model for the PN site (Ecometrix, 2020a) was presented as part of developing the 2020 Groundwater Protection Plan for the PN Site (Ecometrix, 2020b). Eight hydrostratigraphic units (HUs) have been identified beneath PN through historical assessments. HUs are geologic materials that exhibit similar characteristics with respect to storage and movement of groundwater (CH2M Gore & Storrie Limited, 2000). The uppermost HUs (1-3) are fill materials, that are relatively coarse-grained and include compact sands and gravels used for bedding materials for utilities and foundations, and for backfill around station structures. Native materials underlying the fill include high organic content clay materials (HU 4), considered to represent the original ground surface, and tills (HU 5, HU 6, and HU 7). Shale bedrock (HU 8) is encountered at depths ranging from 14-23 m across the site.

The eight HUs have been grouped into four primary groundwater flow systems. These include the "shallow groundwater system" (HU 1-3); "intermediate overburden groundwater system" (HU 6); "deep overburden groundwater system" (HU 7) and the "shallow bedrock groundwater system" (HU 8). Hydrostratigraphic units 4 and 5 are not always observed, and where they are observed, are generally thin and are grouped into the shallow groundwater system. The shallow groundwater system is an aquifer, and the intermediate overburden and bedrock groundwater flow systems are considered to be aquitards. The deep overburden groundwater system may represent an aquifer; however, contaminant migration into this HU from overlying HUs is considered to be limited due to the low permeability of the till materials in HU 6.

There are four main groundwater flow systems present below the PN site reflective of the stratigraphy layers (fill, upper till, lower till and bedrock) (Golder, 2007b) Groundwater flow interpretations for Pickering Nuclear Generating Station (PNGS) were first established in 2002, the 2016-2020 groundwater monitoring program results confirmed that the groundwater flow direction has not changed significantly over time (OPG, 2017c, 2018e, 2019b, 2020e, 2021e). Groundwater contour maps for the fourth quarter of 2019 and 2017 are shown in Figure 2.13 and Figure 2.14 for the shallow (HU 1-3) and intermediate groundwater systems (HU 6). Groundwater elevation monitoring over the past few years has also indicated that there is generally no significant seasonal change in the shallow groundwater flow directions. The predominant shallow groundwater flow patterns are expected to remain unchanged in 2020 from the original site groundwater flow interpretations established in 2002.

In general, vertical flow between the flow systems is downward in the overburden and upward in the bedrock, as would be expected for regional groundwater discharge to Lake Ontario.

The flow in the area of the PN site is significantly influenced by the inactive Turbine Auxiliary Bay foundation drainage system located beneath the deep building foundations. The inactive Turbine Auxiliary Bay foundation drainage system is used to control groundwater beneath the floors. Groundwater from the Turbine Auxiliary Bay foundation drains flows into each unit's sump and then is discharged to the intake channel via pumping. Groundwater from the granular horizons in the Lower Till and the granular foundation backfill is collected in the foundation drains. The drainage system has locally lowered groundwater levels below the level of Lake Ontario, creating a hydraulic sink that capture groundwater beneath and immediately adjacent to the PN reactor buildings (SENES, 2007b). Measured flow into the Turbine Auxiliary Bay foundation drains is on the order of about 25 and 77 m^3/day for PN U1-4 and U5-8, respectively (CH2M, 2000).

Estimated horizontal flow velocities in groundwater across the site range from 0.3 to 11 m/y (CH2M, 2000).

<u>Shallow Groundwater</u>

Shallow groundwater levels are typically within 1 m to 5 m of ground surface throughout most of the site (Ecometrix, 2020a). The highest groundwater levels occur within the area of high ground associated with the East Landfill and the lowest levels occur around the reactor buildings and turbine halls. The shallow groundwater levels measured around the reactor buildings are slightly below lake level, likely reflecting the influence of the reactor building foundation drains and the deep drains beneath the Turbine Auxiliary Bay (Golder, 2007b). All groundwater that discharges to the deep foundation drains flows to each unit's sump where it is then pumped to the inactive drainage common header, followed by a holding pond, and then discharged to the forebay. Closer to the forebay area around the standby generators, the water table is at or slightly above lake level. At the north side of the Turbine Auxiliary Bay within the granular backfill of the CCW discharge duct, the shallow groundwater levels are above the lake level and there is little indication of drawdown to the deep foundation drains.

Shallow groundwater flow directions at the PN site are typically toward Lake Ontario except within the granular fill immediately adjacent to and beneath the powerhouse area at PN U1-4 and U5-8 where groundwater levels are below the level of Lake Ontario and groundwater flow is directed toward the deep foundation drains (Golder, 2007b). Locally, a number of features influence groundwater flows including the fill materials, the East Landfill, the Montgomery Park Road and different surface and subsurface structures. The area of the East Landfill (Figure 2.13) represents a groundwater recharge area, with from the landfill towards the station buildings to the southwest, and towards the lake in the southeast.

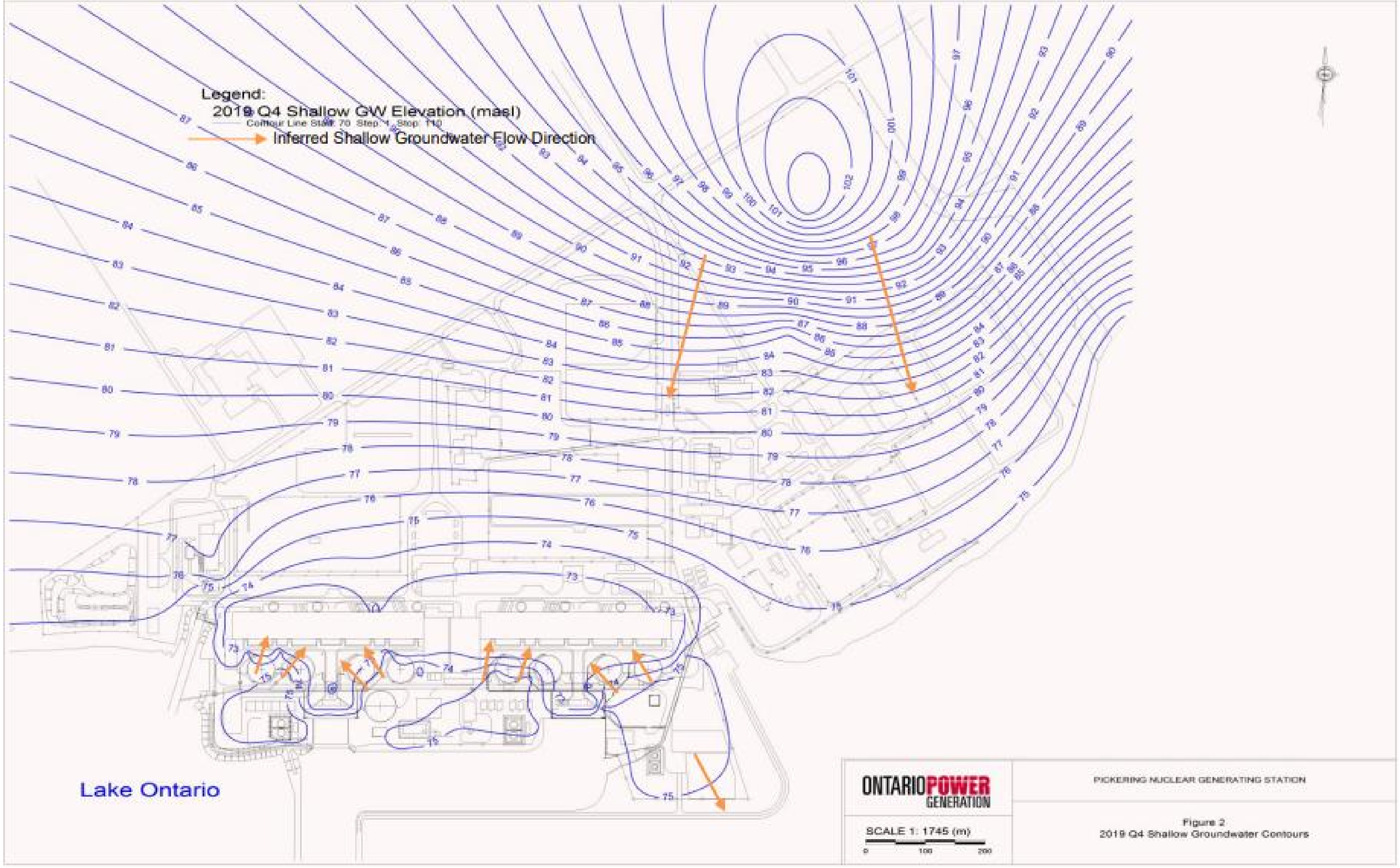
A groundwater divide appears to be present along the northern portion of the PN site that generally runs parallel to Montgomery Park Road. Shallow groundwater north of the Montgomery Park Road flows west towards Frenchman's Bay. In the area south of Montgomery Park Road the direction of groundwater flow is generally to the south towards the station buildings and Lake Ontario. Higher rates of groundwater flow are associated with backfill beneath the building structures, such as the reactor buildings, auxiliary reactor buildings, and the backfill of the CCW intake and discharge ducts. The southerly flow is also locally influenced by structures, including: the Turbine Auxiliary Bay till foundation drain system that acts as a hydraulic sink for the shallow groundwater; and a sump at the base of a ramp to the east of the Vacuum Building that also acts as a local hydraulic sink and results in a small groundwater divide between the reactor buildings and Lake Ontario (Figure 2.13). The Vacuum Building ramp sump discharges to the stormwater sewer system. At the extreme south side of the site, there is a small groundwater flow component towards the lake. Vertically, groundwater flows predominantly downward from the water table (shallow groundwater) to the deep overburden bedrock hydrostratigraphic units.

Intermediate Groundwater

The intermediate groundwater flow system is similar to the shallow system (Figure 2.14), with the East Landfill acting as a recharge area, groundwater north of Montgomery Park Road flowing westward towards Frenchman's Bay and groundwater south of Montgomery Park Road flowing southward towards Lake Ontario. Local influences affecting intermediate groundwater flow include the Turbine Auxiliary Bay drains and Vacuum Building Ramp Sump which create artificial hydraulic sinks similar to those observed in the shallow groundwater system, limiting groundwater flow towards the lake south of the Reactor buildings.

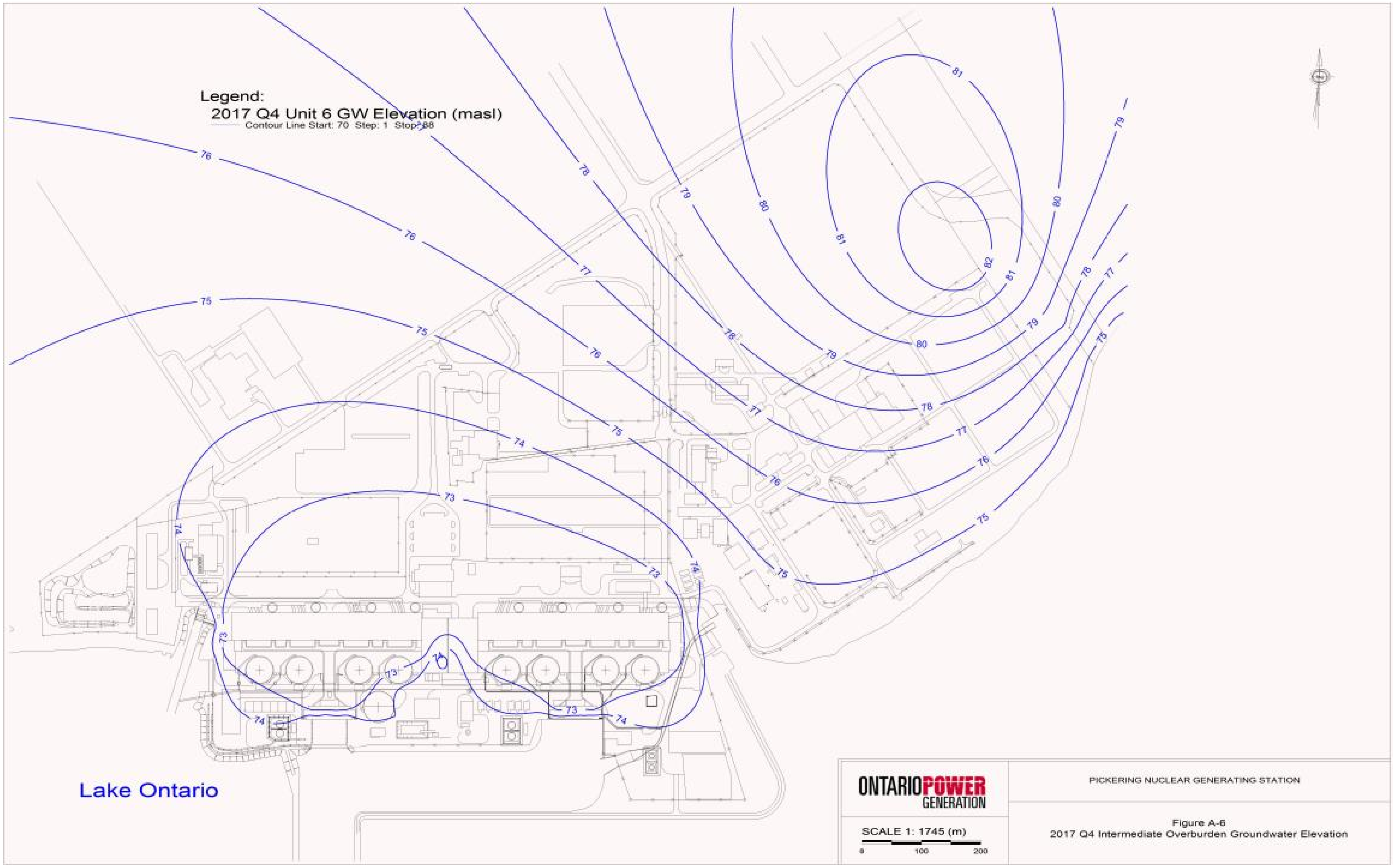
Deeper Groundwater

Due to a limited number of wells located within the deep overburden and bedrock, the deeper groundwater flow systems are less well defined, but the limited data indicate flow towards Lake Ontario with some influence of the Turbine Auxiliary Bay foundation drains. Water levels observed in the Lower Till Complex in the vicinity of PN U1-4 and U5-8 indicate that the deep foundation drains beneath the units are controlling the groundwater levels in the Lower Till Complex through dewatering, indicating that these deep horizons are hydraulically isolated from Lake Ontario (Golder, 2007b). The data also show that the shallow bedrock is typically not influenced by non-nuclear COPCs or by tritium. The shale bedrock at depth beneath the site is of low permeability and is associated with limited rates of groundwater flow except for occasional more permeable fractures that are more prevalent near the bedrock surface (Golder, 2007b).



Source: (OPG, 2020e)

Figure 2.13: Site Groundwater Flow Conditions – Shallow Groundwater Elevation Contours



Source: (OPG, 2018e)

Figure 2.14: Site Groundwater Flow Conditions – Intermediate Groundwater Elevation Contours

2.3.4 Hydrology

2.3.4.1 Lake-wide Circulation and Nearshore Currents

The PN site is situated on the north shore of Lake Ontario. Lake-wide circulation in Lake Ontario is primarily driven by wind and by seasonal temperature effects. The nearshore region currents tend to be driven by brief patterns of strong winds exerting stress at the water surface. The nearshore current typically has a breadth of about 7 km in spring and as much as 10 km in summer and fall (Golder, 2007a).

Table 2.9 shows the frequency of lake current flowing toward each direction and the maximum speed that occurred in each direction for the monitoring period from 2016 to 2020 inclusive. Table 2.10 shows the depth averaged lake current direction and speeds for the same period. Average lake current data are summarized for easterly, NE, ENE, E, and ESE, and westerly, SW, WSW, W, and WNW, lake currents. During the 5-year period including 2016 to 2020, the average easterly and westerly current speeds were 25.2 cm/s and 18.5 cm/s, respectively.

Table 2.9: Lake Current Data from 2016 to 2020

Direction "To"	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Easterly	Westerly
Total Number of Measured Hours	0.0	0.0	17.2	297.2	1483.3	4486.2	8962.5	3954.0	2076.0	2784.0	5686.8	5168.2	695.3	63.8	1.5	0.0	6283.8	11614.2
Percent of Total Measured Hours	0.0%	0.0%	0.05%	0.8%	4.2%	12.6%	25.1%	11.1%	5.8%	7.8%	15.9%	14.5%	1.9%	0.2%	0.004%	0.0%	17.6%	32.6%
Average Speed (cm/s)	N/A	N/A	17.99	20.40	20.76	25.16	26.22	18.39	14.92	14.93	18.14	18.54	15.65	12.55	10.83	N/A	21.08	16.22
Maximum Speed (cm/s)	N/A	N/A	41.49	63.08	65.98	67.87	62.25	49.47	44.54	49.11	56.26	59.34	52.72	45.09	25.60	N/A	67.87	59.34

Notes:
Easterly direction includes NE, ENE, E, and ESE.
Westerly direction includes SW, WSW, W, and WNW.
N/A corresponds to no observed data points.

Table 2.10: Current Speed and Direction from 2016 to 2020

Month	Depth averaged speed – 'E'	Depth averaged speed – 'W'	Percent of Time – 'E'	Percent of Time – 'W'
	cm/s	cm/s		
January	36.1	20.7	5.78%	5.27%
February	33.1	20.8	4.80%	5.83%
March	25.4	19.7	2.10%	8.28%
April	22.7	19.9	3.69%	8.22%
May	18.2	15.3	6.11%	9.63%
June	19.1	12.5	13.86%	8.52%
July	17.0	15.9	13.66%	8.48%
August	20.3	16.9	10.52%	10.30%
September	23.0	18.3	12.81%	9.16%
October	26.7	21.6	12.11%	10.01%
November	29.8	18.9	8.43%	9.41%
December	30.6	21.4	6.14%	6.89%
Average of monthly averages	25.2	18.5	-	-

Notes:
Easterly direction (E) includes NE, ENE, E, and ESE.
Westerly direction (W) includes SW, WSW, W, and WNW.

Nearshore lake currents are affected by the existing operation of the PN units. Some localized effects are observed near water intake and water discharge points. Water velocities in the vicinity of intake groynes are directed toward the plants and a zone of in-flowing water is evident around the intake. With PN U1 and U4 and U5-8 running, typical water withdrawal between the intake groynes and into the plant via the intake channel is estimated at 190 m^3/s based on rated condenser CCW pump capacities and service water demand (SENES, 2007b).

2.3.4.2 Lake Water Temperature

Lake Ontario is generally classified as a dimictic lake because it undergoes a complete cycle of isothermal and vertically stratified conditions in a year. The thermal structure generally depends on the season because of large annual variation in surface heat fluxes. In spring and early summer, heating of the lake surface gradually results in potential formation of thermal stratification conditions, with warmer water at the surface layer and cooler water in the bottom layer. Since nearshore water is heated up more rapidly than offshore water in spring, the depth of the thermocline in shallow water near the shore is greater than the depth of the thermocline in deep water offshore. As deeper water becomes stratified, the thermal bar (i.e., the temperature gradients on the same horizontal plane) moves progressively farther offshore, and it disappears when most of the lake is stratified sometime in June. The lake water is isothermal in fall and winter, or sometimes very weakly stratified in winter. In summer, the nearshore vertical temperature profile demonstrates a stable temperature stratification with warmer water in the surface layer and cooler water in the bottom layer. The depth of the summer thermocline ranges from 5 m to 10 m.

Table 2.11 presents monthly water temperature statistics for Lake Ontario based on monitoring data from 1970 to 1988 for two representative water depths of 1 to 2 m (surface), 8 m and 12 m at an ambient location off PN (Golder, 2007a). These data indicate that the ambient water temperature is lowest in February and peaks in August. The year-to-year variation in monthly mean temperatures is larger in the summer months than in the winter months and is similar at different depths. For comparison, the mean monthly ambient temperature for Lake Ontario collected from the Pickering Acoustic Doppler Current Profiler (ADCP) during the 2016-2020 period is lowest in February and peaks in September.

Table 2.11: Nearshore Mean Monthly Ambient Water Temperatures (°C) for Lake Ontario for the 1970-1988 Period and 2016-2020 Period.

Month	Nearshore Surface Temperature (1970 - 1988)	12-m Depth Temperature (1972- 1988)	>9m Depth Temperature (2016 - 2020)
January	1.6	2.2	2.8
February	1.2	1.8	2.6
March	2.4	2.3	3.2
April	5.3	3.9	4.7
May	7.5	5.8	7.0
June	10.1	7.4	8.3
July	12.9	8.7	12.0
August	17.3	13.5	14.9
September	14.5	12	17.5
October	9.9	8.5	11.1
November	6.0	5.9	6.1
December	3.0	4.3	3.8

2.3.4.3 Thermal Plume Vertical Extent

Between 1986 and 1988, 12 synoptic thermal plume surveys and in-situ water temperature measurements, six during warm weather conditions and six during cold weather conditions, were conducted (Burchat ,1990, cited in (Golder, 2007a)). Warm weather conditions refer to ambient lake water temperatures greater than 4°C and occur in spring, summer, and fall. Cold weather conditions refer to ambient lake water temperatures less than 4°C and occur only in winter. The study was designed to determine the combined effect of the PN units on the aquatic environment with five to seven units in operation. Details of the study are provided in Golder (Golder, 2007a).

The historical data for the 12 synoptic surveys showed that the depth of the thermal plumes under warm weather conditions was 1 to 2 m and that the thermal plumes flowed in the direction of the prevailing wind. The thermal plumes under warm weather conditions extended mostly to the west. The thermal plumes under cold weather conditions extended mostly along the shore and to the east and deeper into the water column.

The historic data also indicated that thermal plumes in winter were generally larger in extent than thermal plumes in summer. Based on a criterion of 2°C above the ambient water temperature, the area of combined PN thermal plumes ranged from 1.5 to 8 km^2 at the water surface regardless of warm or cold weather conditions, and from 0.5 to 3 km^2 at the bottom during cold weather conditions. Results of numerical modelling for winter plumes are presented in Golder (Golder, 2007c).

In 2006 and 2007, a series of anchored buoys, each with temperature loggers at three depths, were set in the vicinity of PN U5-8 to monitor water temperature during normal operations and algae events (Ager et al., 2008). Water temperature contours corresponding to algal events for October 2006 and August - October 2007 were summarized in the report. The results of the field study indicated that PN U5-8 was the dominant thermal discharge plume because of its greater discharge volume and higher discharge temperature differential. PN U1-4 had minimal effects on thermal plumes throughout the study period, because of reduced discharge temperatures and volumes at this Station. The temporal changes observed in the temperature isopleths at the three depth contours were consistent with the development of an elastic floating thermal plume, following a variable initial period of vertical mixing in the vicinity of the PN U5-8 discharge. The development of the floating thermal plume resulted from temperature related differences in the density of the discharge and lake water layers.

Thermal studies during three consecutive winter periods from 2009/10 to 2011/12 were performed to measure lake substrate temperatures in the thermal plume in the vicinity of PN and at reference areas (OPG, 2013a). The study was conducted as follow-up to the Environmental Assessment for the Pickering A Return to Service and the Pickering B Refurbishment to confirm predicted impacts on Round Whitefish spawning or larval development relative to the lake wide population. To represent the region impacted by the PN thermal plume, temperature monitoring locations were established between the Pickering "B" discharge and Duffins Creek. Reference locations included were Thickson Point (Whitby, approximately 13.5 km east of the Pickering site) and Bonnie Brae Point (Oshawa, approximately 19.5 km east of the Pickering Site). The studies demonstrated that the average substrate temperatures at any one location and the degree of difference between substrate temperatures in the area influenced by the thermal plumes and reference areas varied from year to year. Average winter substrate temperatures were slightly warmer in the plume area (by 1 to 2 degrees Celsius) than at the reference locations from December to early March and were similar to reference locations for the remainder of the incubation period to hatch.

As requested by CNSC and ECCC, thermal monitoring was conducted for two additional periods, from December 15, 2018 to March 31, 2019 and from December 15, 2019 to March 31, 2020. The results of the monitoring over the two periods confirm that the average plume temperatures near PN site were 0.3 to 1.4 ºC warmer compared to the average temperature at reference locations (OPG, 2020b), which agrees with the conclusion of the thermal studies from 2009/10 to 2011/12 periods.

2.3.4.4 Thermal Plume Horizontal Extent

The horizontal extent of the thermal plume for PN was studied in 2006 and 2007 (Ager et al., 2008). The greatest extent of the surface plumes (based on a 10°C differential between the ambient temperatures and PN intake temperature) for 2006 were roughly 33,000 m^2, and 40,000 m^2 during October 11-12 and October 27-28 events, respectively. The greatest extent of the surface plumes for 2007 were roughly 53,000 m^2, 34,000 m^2 and 63,000 m^2 during August 21-29, October 9-10, and October 26 -28 events, respectively. Thermal plumes at the middle and bottom contours were more localized. Table 2.12 provides the estimated areas of the surface, middle and bottom thermal plumes where the temperature was greater than 10°C above the PN U5-8 intake temperature observed during the 2006 – 2007 algal events. The depth of each water temperature contour (surface, middle, and bottom) was variable.

Table 2.12: Estimated Area of the Surface, Middle and Bottom Thermal Plumes (10°C above the Units 5-8 Intake Temperature) during Algal Events Observed in 2006 and 2007

Event		Temperature Contour	
		10°C Above the PN U5-8 Intake Temperature	
Year	Date	Depth	Maximum Area (m^2)
2006	October 11-12	Surface	33,425
		Middle	9,750
		Bottom	8,325
2006	October 27-28	Surface	40,800
		Middle	13,325
		Bottom	12,850
2007	August 21-29	Surface	53,475
		Middle	24,000
		Bottom	3,300
2007	October 9-10	Surface	33,975
		Middle	20,100
		Bottom	125
2007	October 26-28	Surface	62,625
		Middle	24,175
		Bottom	11,375

Source: Tables 9 to 14, (Ager et al., 2008)

2.3.4.5 Surface Drainage

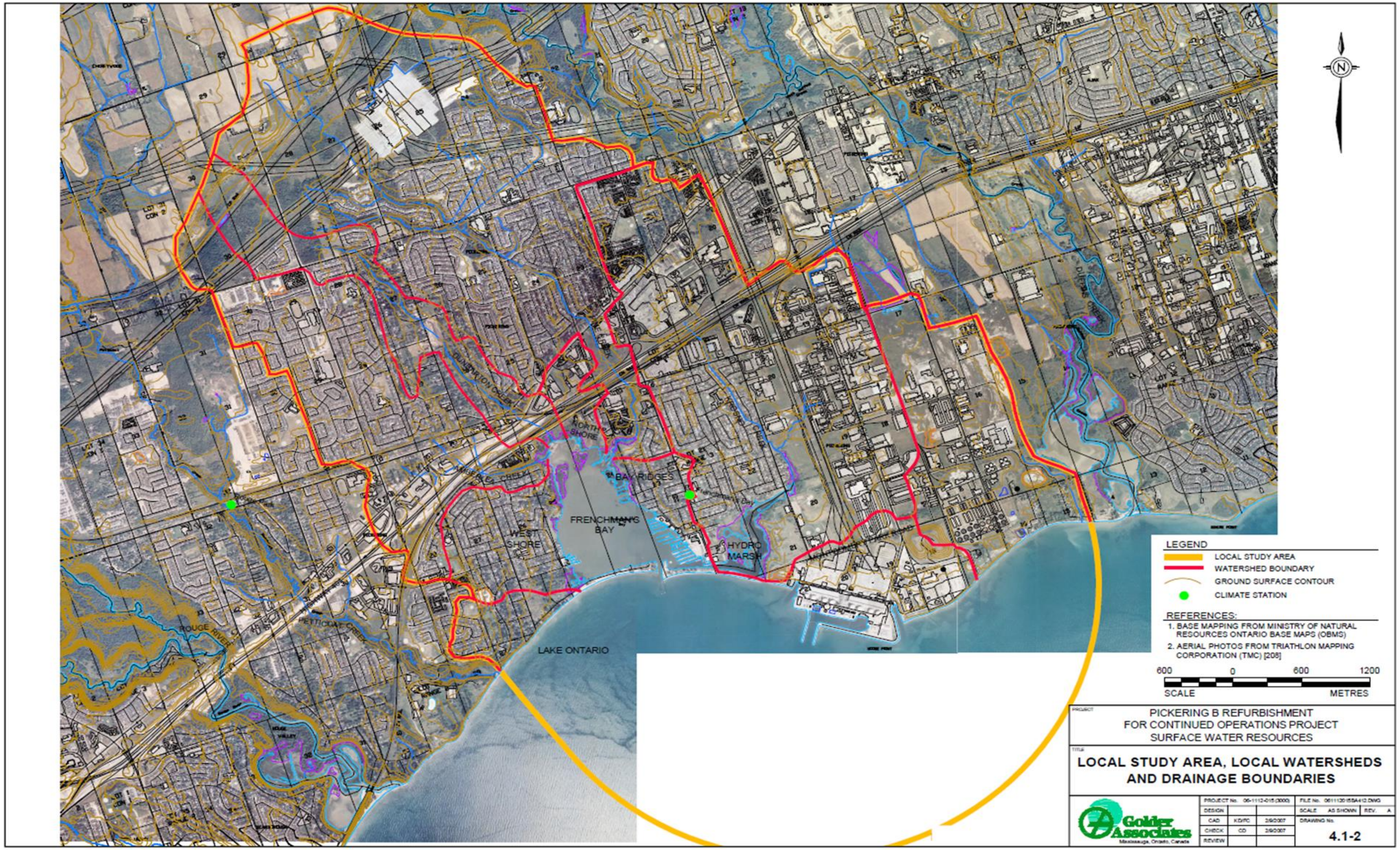
Lake Ontario is the farthest downstream of the five Great Lakes. It is the smallest in surface area but is substantially larger in volume, 1,640 km^3, than Lake Erie, which is located immediately upstream and empties into Lake Ontario via the Niagara River. The land area draining directly to

Lake Ontario is approximately 64,030 km^2. The Niagara River constitutes the single most significant inflow to Lake Ontario. The natural outlet from Lake Ontario is the St. Lawrence River.

The Lake Ontario watershed boundary in the region of the PN site is defined by a topographic high corresponding to the Oak Ridges Moraine which forms the watershed divide between Lake Ontario and Georgian Bay. From west to east, the main drainages to Lake Ontario within the region, include Don River, Highland Creek, Rouge River, Petticoat Creek, Frenchman's Bay, Duffins Creek, Carruthers Creek, Lynde Creek, Oshawa Creek, and Harmony Creek and Farewell Creek watersheds.

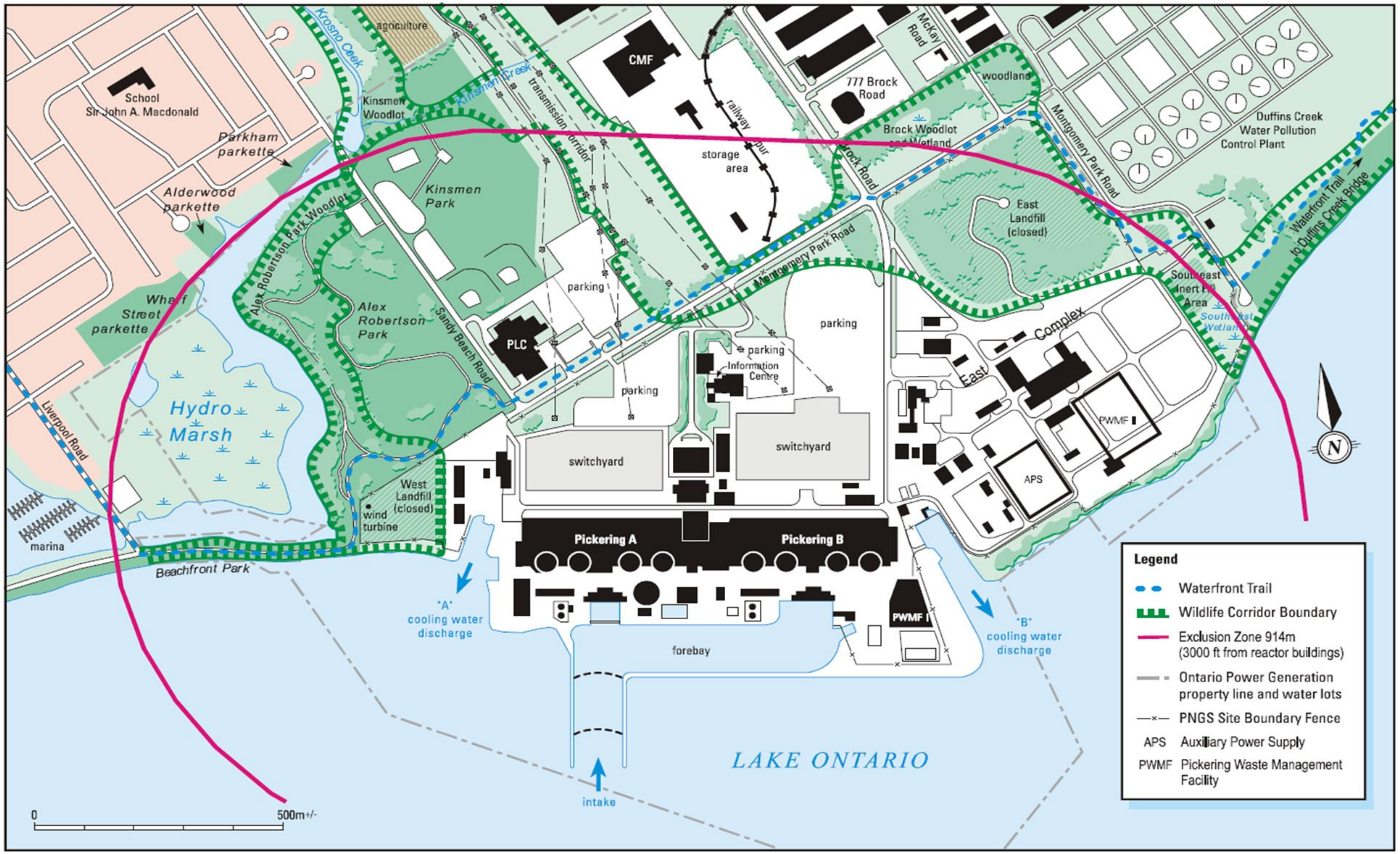
The PN site is surrounded by two major watersheds: the Rouge River watershed to the west and the Duffins Creek watershed to the east, as shown in Figure 2.15. Two smaller watersheds are located between the Rouge River watershed and the PN site. These are the Petticoat Creek watershed and the watershed draining to Frenchman's Bay, which are 26 km^2 and 22 km^2, respectively. The watershed draining to what has been referred to as the "Hydro Marsh", located directly west of the PN site (see Figure 2.15), includes flow from Krosno Creek which has a watershed of 0.7 km^2 and is a tributary of Frenchman's Bay. Krosno Creek also drains 0.14 km^2 of Hydro One's central maintenance and storage areas north of Montgomery Road.

Drainage in the PN site is a mix of ephemeral swales, ditches, culverts and storm sewers. Stormwater runoff from the PN site is collected by the stormwater drainage system and directed through drainage pathways south to Lake Ontario. No major watercourses traverse the SSA and no waterbody other than a small (5000 m^2) isolated wetland known as the Southeast Wetland is located in the SSA. This small isolated wetland, which lies in the southeast corner of the PN property at the foot of Montgomery Park Road was once farmland and was created during the construction of PN as a result of landfilling activities. The Southeast Wetland receives drainage from the area around the former construction landfill within the SSA, and at best remains seasonally wet. Figure 2.16: PN Site Plan provides a site plan for the PN site including the location of Hydro Marsh, the Southeast Wetland Area, PN U1-4 and U5-8 discharges and the PN water intake channel. In addition, there is a small manmade ephemeral pond in Alex Robertson Park.



Source: (Golder, 2007a)

Figure 2.15: Local Study Area for Surface Water Resources, Local Watersheds and Drainage Boundaries



Source: (Golder, 2007a)

Figure 2.16: PN Site Plan

2.3.5 Vegetation Communities

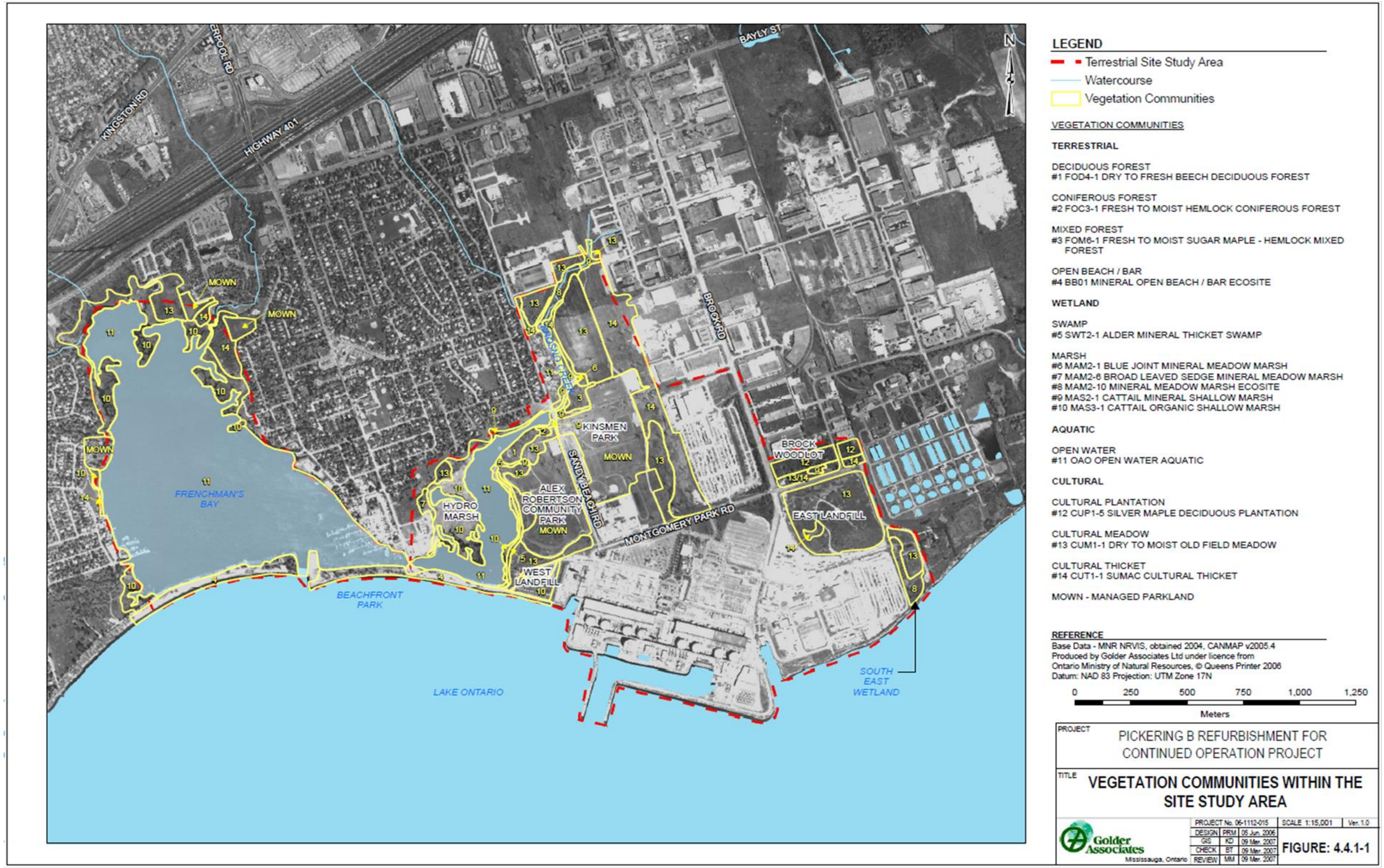
This section provides a brief overview of regional vegetation communities and summarizes existing vegetation communities located in the terrestrial SSA, as shown on Figure 2.17: Vegetation Communities Within and in the Vicinity of the PN Site. The site, local and regional vegetation communities and other components of the terrestrial environment are briefly described below and in greater detail in (Golder, 2007d).

Much of the regional area has been cultivated over the past century. Accordingly, the dominant vegetation cover is related to agricultural use, including cash crops and pasture land. Other natural vegetation features are associated with valley lowlands associated with rivers and creeks, and the Lake Ontario shoreline environment. The flora of the RSA generally falls into the Niagara section of the Deciduous Forest Region (Rowe, 1972 as cited in Golder, 2007c). Dominant tree species in the natural forest areas in the vicinity of the PN site include: Beech, Sugar Maple, Basswood, Red Maple, White Oak and Bur Oak. The coastal wetlands, located between the permanent, deep water of the lake and the dry uplands area, contain a mix of plant communities. Examples of vegetation communities in coastal wetlands include treed and thicket swamps, wet grass and sedge meadows, and emergent marshes that contain plants such as cattails and bulrushes. Coastal wetlands often contain interspersed pockets of open water that support submerged and floating leafed plants such as pondweeds and waterlilies.

Vegetation communities within and in the vicinity of the PN site are identified in (Golder, 2007d) shown on Figure 2.17: Vegetation Communities Within and in the Vicinity of the PN Site and from Toronto and Region Conservation Authority (TRCA) studies from 2009 to 2015 (TRCA, 2014, 2015), shown on Figure 2.18: Terrestrial Monitoring Plots within the PN Site.

The vegetation communities in (Golder, 2007d) were identified based on the Ontario Ministry of Natural Resources (OMNR) Ecological Land Classification (ELC) for Southern Ontario (Lee et al., 1998, cited in Golder, 2007c). The vegetation communities are classified into four terrestrial communities (#1 to #4), six wetland communities (#5 to #10), one open water community (#11) and four cultural communities (#12 to #14). As shown in the figure, the portion of the PN site south of Montgomery Park Road is largely dedicated to industrial use while most of the PN site north of Montgomery Park Road is vegetated. The vegetated lands north of Montgomery Park Road are occupied by public parkland, athletic fields and a transmission corridor. This is consistent with site observations by an ecologist during an inspection on May 20, 2015.

In 2009, Toronto and Region Conservation Authority (TRCA) biologists were contracted to establish a terrestrial long-term monitoring project on PN property (OPG, 2011b), following the conservation authority's regional monitoring protocol in forest, wetland and meadow habitat types. Monitoring stations are presented in Figure 2.18: Terrestrial Monitoring Plots within the PN Site The purpose of the inventory was to detect changes and trends in the flora and fauna communities over time. A summary analysis and report was completed after 5 years of data collection from 2009 to 2013 (TRCA, 2014). Monitoring results for 2009 to 2015 are summarized in this report (TRCA, 2014, 2015).



Source: (Golder, 2007a)

Figure 2.17: Vegetation Communities Within and in the Vicinity of the PN Site

Source: (TRCA, 2014)

Figure 2.18: Terrestrial Monitoring Plots within the PN Site

2.3.5.1 Terrestrial Vegetation Communities

The terrestrial vegetation systems are upland areas where the water table is normally below the substrate surface. Four terrestrial community types were identified in the vicinity of PN, including deciduous, coniferous, and mixed forest areas, and an open beach/bar.

Forest Communities

The forest communities are small independent areas (less than 2 ha) located along Krosno Creek upstream of Hydro Marsh (Figure 2.17). They include a 1.57 ha remnant deciduous forested area at the north end of Alex Robertson Park, a 0.25 ha coniferous forest community located within the Alex Robertson Woodlot and a 1.07 ha remnant mixed forest area located just north of Kinsmen Park. The three forest communities generally consist of mature trees which form a closed canopy and result in a poorly defined shrub layer. Open canopy conditions are present in the south end of the deciduous forest community of Alex Robertson Park resulting in an abundant shrub layer. Two Butternut trees (designated as a nationally endangered species (Schedule 1 SARA and Committee on the Status of Endangered Wildlife in Canada (COSEWIC)), provincially endangered by the Committee on the Status of Species at Risk in Ontario (COSSARO) and protected under Ontario's *Endangered Species Act*) are present along the north edge of the Mixed Forest lot north of Kinsmen Park. Plant species at risk are further discussed in Section 2.3.5.5. Designations for plant species can be updated from time to time and are current to the time of publication.

The two forest areas included in the 2009 to 2013 survey, the Kinsmen Woodlot (FV-25A) and the Brock Woodlot (FV-25B) (Figure 2.17) differ in age, structure and species composition and are fragmented and isolated from other native habitat patches (TRCA, 2014). However, the overall tree health was deemed to be good.

According to TRCA (2014), the Kinsmen Woodlot is natural in origin, and supports a range of common forest species. Sugar Maple (*Acer saccharum*) was the dominant tree species in the forest plot FV-25A and native Chokecherry *(Prunus virginiana)* was the dominant shrub. Over the five-year period of the study, native species richness at FV-25A in the shrub layer remained relatively consistent but the prevalence of non-native species Common Buckthorn *(Rhamnus cathartica)*, European Highbush Cranberry *(Viburnum opulus ssp. opulus)* and Garden Red Currant *(Ribes rubrum)*, increased to the detriment of the native species to 6% of total relative abundance and to 2.2% of total ground cover in 2013. Twenty-six species were identified in the ground layer at FV-25A which included a mix of native and non-native species. The dominant species, Virginia Waterleaf (*Hydrophyllum virginianum*), Garlic Mustard (*Alliaria petiolata*), and Yellow Trout Lily (*Erythronium americanum ssp. americanum)* accounted for over 90% of the ground cover. Between 2011 and 2013, the percent ground cover by native species in the ground layer showed an overall decrease from about 93% to 72% while non-native species such as Garlic Mustard showed an increase.

The TRCA (2014) describes the Brock Woodlot as a disturbed plantation. The plantation which was established in the 1980s has an open canopy which facilitates the growth of underlayers of vegetation. Overall, the vegetation community at the Brock Woodlot is dominated by non-native species. The tree community at FV-25B consists of Red Ash (*Fraxinus pennsylvanica*), Black Locust (*Robinia pseudoacacia*), Basswood (*Tilia americana*), and Silver Maple (*Acer saccharinum*). The dominant shrubs include Wild Red Raspberry (*Rubus idaeus ssp. strigosus*), European Highbush Cranberry and Chokecherry. Nineteen species were recorded in the herbaceous subplots between 2011 and 2013, of which eight were native and eleven were non-native. Eighty-nine percent of the total cover (2011-2013 average) was provided by 3 non-native species including: Urban Avens (*Geum urbanum*); Garlic Mustard (34%); and Dog-Strangling Vine (*Cynanchum rossicum (Kleopow) Borhidi)*. The latter two species have been showing an increase in cover over time at the Brock Woodlot to the detriment of native and other non-native species.

Open Beach/Bar Community

The open beach/bar is confined along the Lake Ontario shoreline, east and west of the mouth of Frenchman's Bay (Figure 2.17). This vegetation community is confined to an area near the water level that is generally subject to active shoreline processes including periodic high water levels, wave action, erosion, deposition and ice scour. The southern portions of this community, adjacent to the lake, generally support sparse vegetation cover. The vegetation cover increases in the central and northern portions of this community where wave action and ice scour occur less frequently. The structure of this vegetation community generally consists of old field vegetation and tree and shrub regeneration. The north part of the eastern bar adjacent to Hydro Marsh is protected for naturalization. A habitat restoration area has been established north of the boardwalk on the eastern bar. This area has been planted with species historically found on beaches of the Great Lakes.

Landfill Plant Community

In 2013, the TRCA conducted a flora inventory of the East Landfill located within the southeast corner of the PN site (TRCA, 2013). The landfill area consists of 17 hectares of undisturbed habitat that is fenced from any direct human disturbance. Detailed field work at the East Landfill was undertaken in 2013 to characterize the terrestrial natural heritage features of the study area. Twenty-three vegetation types were identified in the study area, including a large area of meadow, a young plantation and a poplar forest, wetland areas and successional habitats, and a small coastal strip with beach and bluff. The landfill area has been planted with almost exclusively non-native species; a total of 204 flora species were observed in 2013; including successional and wetland species. In comparison, the total study area surveyed in 2008, which occupies 113.5 hectares (TRCA, 2009a), has 288 flora species (TRCA, 2013).

2.3.5.2 Wetland Vegetation Communities

Wetland vegetation systems include areas where water levels fluctuate and are less than 2 m in depth. One swamp thicket area and five marsh areas were identified within and in the vicinity of the PN site (Figure 2.17).

The swamp thicket area is a narrow linear community located along the east margin of Hydro Marsh and forms a riparian interface between Hydro Marsh and the lower slope area of Alex Robertson Park. The vegetation is dominated by shrubs, especially speckled alder. The lower slope area of this community, where a drier soil regime is present, supports shrubs, including raspberry and elderberry, and planted trees, including Silver Maple and Cottonwood.

The marsh communities are classified by vegetation and environmental characteristics, such as duration of flooding, substrate type, disturbance and available nutrients. Marsh communities around Frenchman's Bay, Hydro Marsh and in the West Landfill area of PN grow on organic substrates, while the marsh communities in the upper section of Krosno Creek and the eastern portion of the PN site grow on mineral materials substrates. Three of the marsh communities are classified as meadow marshes indicating that the wetland-terrestrial interface is seasonally inundated with water and usually dominated by grasses or forbes. Two marsh communities are classified as shallow marshes, indicating that the water table rarely drops below the substrate surface and the vegetation community is composed primarily of broad-leafed or narrow-leafed emergent species. The wetland communities associated with the central and western portions of Hydro Marsh and the central and northern portions of Frenchman's Bay are organic shallow marshes dominated by dense stands of broad-leaf cattail and narrow-leaf cattail. The Southeast Wetland situated at the eastern shoreline of the PN site is classified as a mineral meadow marsh ecosite. The Southeast Wetland is on a poorly drained mineral soil that receives runoff from adjacent lands from the west and north, as well as stormwater drainage through a culvert under the southern end of the Montgomery Park Road. The vegetation community is dominated by common reed but includes pockets of dense shrub growth and sporadic tree growth.

<u>Hydro Marsh Wetland Communities</u>

Two wetland areas in Hydro Marsh were monitored as part of 2009 to 2013 Terrestrial Long-Term Monitoring Project study (TRCA, 2013) upstream of the eastern bar (Figure 2.17: Vegetation Communities Within and in the Vicinity of the PN Site). The two wetland plots were dominated by cattail marsh. Neither supported a tree canopy. The wetland characterized by plot WV-18A covered more aquatic habitat and plot WV-18B included terrestrial shoreline habitat. The study determined that fluctuating water levels have been the main driving force in determining the presence of species across the monitored wetland communities, but overall, the floristic quality and species richness has remained stable over the study period. Although non-native species, particularly hybrid cattail (*Typha x glauca*), were prominent in both wetlands areas, native species provided the greatest proportion of cover and species richness.

Speckled Alder (*Alnus incana ssp. rugosa*), was the dominant woody plant at WV-18A and accounted for the greatest percent cover for any species, followed by the non-native species, Bittersweet Nightshade (*Solanum dulcamara*). Sweet Gale (*Myrica gale*), a species of regional concern, was also present at WV-18A. A total of 48 species were found in the ground vegetation composition between 2009 -2013, of which 31 were native. The ground layer was dense and lush in particular along the lower half of WV-18A, and species density and diversity decreased as WV-18A extends into the open water. The species that were encountered most frequently in the coastal community included Hybrid Cattail, Common Duckweed *(Lemna minor),* Purple Loosestrife *(Lythrum salicaria*) and European Frog-bit (*Hydrocharis morsus-ranae*).

Plot WV-18B has a sparse distribution of woody species which is dominated by native species including Long-spined Hawthorn (*Crataegus macracantha*) and Wild Red Raspberry. The dominant species which composed the ground vegetation layer included Hybrid Cattail, Common Duckweed, Awned Sedge (*Carex atherodes*), European Frog-bit and Orange Touch-me-not (*Impatiens capensis*).

2.3.5.3 Open Water Vegetation Community

Open water vegetation communities are generally aquatic communities in which the permanent water is generally deeper than 2 m and the total vegetation cover is greater than 25%. An open water vegetation community occupies the majority of Frenchman's Bay and the main channel associated with the lower reaches of Krosno Creek and Hydro Marsh. In Hydro Marsh, most of the open water is less than 0.5 m deep and substrates in the upstream areas can be exposed depending on the water level in Lake Ontario. Aquatic vegetation is sparse and is limited to isolated pockets of floating duckweed species.

2.3.5.4 Cultural Vegetation Communities

Cultural vegetation communities originate from or are maintained by anthropogenic influences and culturally based disturbances. They often contain a large proportion of non-native species. In addition to large areas of mown parkland located in the Alex Robertson Park and the Kinsmen Park, three cultural community types were identified within or in the vicinity of the PN site, including a cultural plantation, a cultural meadows and cultural thicket (Figure 2.17 and Figure 2.18).

The 2.3 ha forested area located north of Montgomery Park Road and east of Brock Road, the Brock Woodlot, is a disturbed plantation which TRCA (2014) classifies as a Silver Maple Deciduous Plantation. The woodlot consists of rows of Silver Maple, White Ash, Black Locust and Eastern Cottonwood, oriented in an east-west direction.

Cultural meadows are open vegetation communities that support less than 25% tree cover and less than 25% shrub cover. These communities develop in areas that have not been subjected to mowing practices and typically represent an early stage of natural succession. This vegetation type is the most common community type at the PN site. Cultural meadow vegetation occurs throughout the East and West Landfill Sites, adjacent to the Southeast Wetland, along portions of the hydro corridor, along the south side of the Brock Woodlot and in areas of Alex Robertson Park that have been allowed to naturalize (Figure 2.17: Vegetation Communities Within and in the Vicinity of the PN Site).

Cultural thickets are characterized by tree cover less than 10% and tall shrub cover greater than 25%. These communities represent a more advanced state of natural regeneration than cultural meadow areas. Within the PN site, cultural thicket vegetation is most predominant along the east side of the hydro corridor. These communities consist of old field meadow species and thicket vegetation that has been allowed to naturalize for some time. Shrubs are densely arranged in most areas, and openings within the thicket vegetation is dominated by herbaceous species typical of cultural meadow communities.

2.3.5.5 Vegetation Species at Risk

A list of the plant species that have been recorded at the PN site, along with their regional federal and provincial species at risk status ranking, is provided in (Golder, 2007d) and (OPG, 2016b). The list includes observations from the 2016 to 2020 inventories and biodiversity studies as well as earlier referenced observations for the area. Four plant species (Table 2.13) with a status of threatened or endangered were recorded at the PN site.

Table 2.13: Plant Species at Risk Observed within the PN Site Area

Scientific Name	Common Name	Federal Species at Risk Status (1)	Provincial Ranking (2)	Most Recent Year Observed
Juglans cinerea	Butternut	Endangered	Endangered	2020
Lespedeza virginica	Slender bush-clover	Endangered	Endangered	2000
Gymnocladus dioicus	Kentucky coffee-tree	Threatened	Not listed (3)	2000
Morus rubra	Red mulberry	Endangered	Endangered	2000

Notes:
The Provincial Species at Risk in Ontario List, Federal List of Wildlife Species at Risk (Schedule 1 of the Species at Risk Act (SARA)), and COSEWIC list are frequently revised.
(1) SARA Schedule 1 ranks species at risk as Extirpated, Endangered, Threatened Species and Special Concern. Prohibitions of the Act do not apply to species of Special Concern. COSEWIC is also included.
(2) The provincial Endangered Species Act (2007) came into effect on June 30, 2008 and it applies to these species once they appear on the official list.
(3) Kentucky Coffee-tree has a provincial status of "Threatened" only in the following geographic areas: the County of Elgin, the County of Essex, the County of Lambton, the County of Middlesex, the County of Norfolk, the County of Oxford and the Municipality of Chatham-Kent. PN is not located in any of these geographic locations.
Sources: (Beacon, 2020a; OPG, 2016b; TRCA, 2014)

Butternut was identified in TRCA (2009) as being in the Fresh-Moist Sugar Maple – Hemlock Mixed Forest ELC and was identified in 2013 in Kinsmen Park. One mature Butternut tree was observed in 2019 and 2020 (Beacon, 2019, 2020b), which is located in Alex Robertson Park at the entrance to the trail from the parking lot off of Sandy Beach Road. The other plant species at risk identified in Table 2.13 have not been observed since 2000. Red Mulberry and Slender Bushclover have not been located in any recent observations; and Kentucky coffee-tree is no longer considered part of the PN Species list (Beacon, 2020a).

2.3.5.6 Wildlife Habitat

Wildlife habitat is associated with the vegetation communities and natural and developed areas found within. This section summarizes the potential use of different vegetation communities by wildlife species that have been recorded at the PN site.

2.3.5.6.1 Wildlife Habitats and Terrestrial Wildlife Species Lists

Detailed description of wildlife communities and species recorded at the PN site and their use of the different habitats is provided in (Golder, 2007d). Documentation of wildlife communities and species derived from historical records, wildlife mortality survey work conducted for the Pickering A Return to Service Environmental Assessment and associated follow-up and monitoring undertaken from 2004 to 2006 were reviewed (Golder, 2007d). These documents reported three amphibian species, seven reptile species, 247 bird species and 23 mammal species occurring within or in the vicinity of the PN site.

The current up to and including 2020 Pickering Nuclear Generating Station Study Area Species Lists (Beacon, 2020a) documented a total of 775 species of flora and fauna at the PNGS broken into the following groups of wildlife: 27 mammals, 10 reptiles and amphibians, 242 birds, 26 butterflies and moths, 26 dragonflies and damselflies, 66 fish, and 378 species of vascular plants.

The big brown bat (*Eptesicus fuscus*), red bat (*Lasiurus borealis*) and silver-haired bat (*Lasionycteris noctivagans*) were last observed on the PN site in 2020 in Alex Robertson Park (OPG, 2002a). Based on site observations on May 20, 2015 by an ecologist, bat habitat is not apparent on the PN site as most of the buildings would not provide suitable bat habitat. Suitable bat habitat was apparent in the woodlots adjacent to the PN site. Bats are commonly observed in Alex Robertson Park and along Montgomery Road during the bat monitoring surveys conducted as part of the PN site biodiversity program.

The presence of birds was documented as part of the 2009 to 2013 Terrestrial Long-Term Monitoring Project study (TRCA, 2014) and as part of the 2015 monitoring season (TRCA, 2015). Most of the bird species observed were considered to be secure in the urban landscape of the greater Toronto region. The results of species observed for each area (forest, wetland and meadow) are listed in Table 2.14 and summarized in this section.

Table 2.14: Bird Species Observed During the 2009 to 2015 Terrestrial Long Term Monitoring Project

Species		Habitat		
Scientific Name	**Common Name**	**Wetlands**	**Meadow**	**Forest**
Wetland Species				
Branta canadensis	Canada Goose	√	-	√
Gallinula chloropus	Common Moorhen	√	-	-
Geothlypis trichas	Common Yellowthroat	√	√	-
Anas strepera	Gadwall	√	-	-
Ixobrychus exilis	Least Bittern	√	-	-
Anas platyrhynchos	Mallard	√	-	-
Porzana carolina	Sora	√	-	-
Melospiza georgiana	Swamp Sparrow	√	-	√
Rallus limicola	Virginia Rail	√	-	-
Cistothorus palustris	Marsh Wren	√	-	-

Species		Habitat		
Scientific Name	**Common Name**	**Wetlands**	**Meadow**	**Forest**
Meadow Species				
Tyrannus tyrannus	Eastern Kingbird	√	√	√
Actitis macularius	Spotted Sandpiper	√	-	-
Empidonax traillii	Willow Flycatcher	√	√	-
Forest Species				
Polioptila caerulea	Blue-grey Gnatcatcher	-	-	√
Myiarchus crinitus	Great-crested Flycatcher	-	-	√
Contopus virens	Eastern Wood-pewee	-	-	√
Vireo olivaceus	Red-eyed Vireo	-	-	√
Setophaga ruticilla	American Redstart	-	-	√
Picoides pubescens	Downy Woodpecker	-	-	√
Melospiza melodia	Song Sparrow	√	√	√
Poecile atricapillus	Black-capped Chickadee	-	-	√
Quiscalus quiscula	Common Grackle	√	-	√
Dumetella carolinensis	Grey Catbird	√	√	√
Cardinalis cardinalis	Northern Cardinal	√	-	√
Agelaius phoeniceus	Red-winged Blackbird	√	√	√
Sitta carolinensis	White-breasted Nuthatch			√
Pheucticus ludovicianus	Rose-breasted Grosbeak		√	
Generalist Species				
Setophaga petechia	Yellow Warbler	√	√	√
Spinus tristis	American Goldfinch	-	√	√
Turdus migratorius	American Robin	-	√	√
Bombycilla cedrorum	Cedar Waxwing	-	√	√
Zenaida macroura	Mourning Dove	-	√	√
Mimus polyglottos	Northern Mockingbird	-	√	-
Icterus galbula	Baltimore Oriole	√	√	√
Cyanocitta cristata	Blue Jay	-	-	√
Colaptes auratus	Northern Flicker	-	-	√
Icterus spurius	Orchard Oriole	-	√	-
Buteo jamaicensis	Red-tailed Hawk	-	√	-
Vireo gilvus	Warbling Vireo	-	-	√
Molothrus ater	Brown-headed Cowbird*	-	√	√
Sturnus vulgaris	Eurasian Starling			√
Passer domesticus	House Sparrow			√

Notes:
√ indicates that the species was observed
- Indicates that the species was not observed
* brown-headed cowbird is a brood parasite, i.e. does not nest
source: TRCA, 2014; 2015

Wetlands

Marsh and swamp habitat is found both in Frenchman's Bay Marsh and Hydro Marsh and extends to a limited degree in Krosno Creek upstream of Sandy Beach Road. A small marsh habitat also occurs in the naturalized area to the south of East Landfill (referred to as the southeast wetland) and along the south edge of the West Landfill. Frenchman's Bay and Hydro Marsh contain a large area of open shallow water surrounded by a cattail perimeter. The open water portion of the marsh does not contain emergent vegetation so this portion is used primarily by gulls, ducks, geese and swans for limited foraging for items such as insects, while the perimeter areas are used by a variety of bird species for nesting and foraging. Birds that may use the perimeter areas include Red-winged Blackbird and Black-crowned Night Heron. The open water and perimeter areas are used by aquatic mammals, such as Muskrat, amphibians (American Toad, Green Frog and Northern Leopard Frog) and reptiles (Snapping Turtle, Midland Painted Turtle, Northern Map Turtle, Blanding's Turtle, Red-eared Slider, Eastern Garter Snake, Dekay's Brownsnake).

During the 2009 to 2013 study, a total of 20 bird species were identified at two wetland bird stations in Hydro Marsh (TRCA, 2014). As shown in Table 2.14, 10 of the 20 bird species were wetland associated species, three were meadow associated species and the rest were generalist species.

Six frog species have been observed in wetlands in the vicinity of the PN site, including at Hydro Marsh, Frenchman's Bay and Durham Marsh between 2007 and 2014. These include Northern Leopard Frog, Gray Treefrog, Spring Peeper, American Toad, Green Frog, and Chorus Frog. Also, during the 2009 to 2013 study, three frog species, American Toad, Green Frog and Leopard Frog, were observed, but at very low numbers. The American Toad and Leopard Frog were also observed during the 2018 amphibian monitoring as part of the PN site biodiversity program (Beacon, 2018).

Woodland

Woodland refers to a treed community having 35% to 60% cover by coniferous or deciduous trees. Woodland habitat within the PN site is generally limited to the Brock Woodlot and Alex Robertson Woodlot, as well as the wooded area along the east edge of Krosno Creek. Woodland habitat is used for nesting foraging and roosting by resident and migratory bird species. Small mammals will also use these sites for shelter, foraging and reproduction.

As shown in Table 2.14, a total of 28 bird species were identified at two forest bird stations at the PN site during the 2009 to 2013 study (TRCA, 2014). The majority of the species observed, fifteen, were woodland or generalist species. The presence of two wetland and one meadow species in the forest bird count was attributed to the areas in which the bird counts were completed, which overlapped wetland or meadow areas because of the relatively small size of the forest area.

Shrubland

Shrubland habitat occurs at the edge of the woodland habitat areas and in areas where trees and shrubs have been permitted to grow at coverage percentages <35% to 60%. Shrubland habitat is located at the south edge of the Brock Woodlot and along the west side of Alex Robertson Community Park adjacent to the Hydro Marsh and its woodland areas. Shrubland habitat also occurs in the beach/bar, Alder Mineral Thicket Swamp, Broad-leaved Sedge Mineral Meadow Marsh, Mineral Meadow Marsh Ecosite and the Sumac Cultural Thicket communities show on Figure 2.17: Vegetation Communities Within and in the Vicinity of the PN Site. This transitional habitat between field and forest is used by a combination of field and woodland bird species that prefer dense shrub cover for nesting and foraging and by small mammals for shelter, foraging and reproduction.

Open Grassland

Open grassland includes those open areas that are either natural or seeded and then left in a relatively natural state. Open grassland habitat is available in the cultural meadow vegetation of the East and West Landfills, adjacent to the Southeast Wetland, along portions of the hydro corridor, along the south side of the Brock Woodlot and in areas of Alex Robertson Park that have been allowed to naturalize. Open grassland can provide habitat for species that prefer grassland and prairies. It will be used by birds for nesting, foraging and shelter, and small mammals for shelter, foraging and reproduction.

One meadow station (MB-15A) was set up during the 2009 to 2013 study (Figure 2.17: Vegetation Communities Within and in the Vicinity of the PN Site). During the 2009 to 2013 study, a total of 205 bird species were identified at two forest bird stations at the PN site. The meadow station was dominated by species that do not have any specific association with meadow-habitat (Table 2.14), and would likely persist at the site even if the meadow habitat were to succeed to shrub habitat and then to early successional forest (TRCA, 2014).

Parkland

Parkland is those habitats that are managed for recreational or aesthetic purposes. Parkland habitat includes portions of Kinsmen Park, Alex Robertson Community Park, and the various areas of maintained lawn. While habitat is limited in this area due to the lack of vegetation cover and diversity, certain species, such as swallows, nighthawks, swifts and bats, will make use of the open area to forage.

Shoreline and Open Water Habitat

Shoreline habitat consists of the Open Beach/Bar community shown in Figure 2.17: Vegetation Communities Within and in the Vicinity of the PN Site. Figure 2.17: Vegetation Communities Within and in the Vicinity of the PN Site. This area provides a small amount of habitat for loafing and foraging by waterbirds, particularly wading birds and geese. The open water portions of the PN site are also used by waterbirds for resting and foraging, and provide feeding opportunities for resident species such as ducks, gulls, terns and swans.

Pickering Nuclear Built Environment

The PN site includes buildings and man-made structures that provide habitat for wildlife. Buildings provide habitat suitable for common urban bird species and rodents that are tolerant of noise and activity associated with the daily operations of the station. Habitat conditions within the envelope of the generating station buildings are typically marginal due to the lack of cover, shelter and food. The taller buildings and their auxiliary structures provide opportunity for raptors, such as Peregrine Falcon, and other species to scan for food sources and provides roosting opportunities for other species such as doves and sparrows. The Black-crowned Night Heron, which is classified as a vulnerable species in the province, is commonly observed roosting on cables across the PN U5-8 discharge channel. Several of the buildings on the PN site may provide a suitable habitat for the Barn Swallow. Much of the PN built environment occurs within fenced areas, restricting the movement of larger mammals within this area; however, White-tailed Deer and Red Fox are occasionally recorded within the fenced areas. Red Fox den sites are located within the fenced area. The constructed shoreline, where the station meets Lake Ontario, consists of large areas of armour stone. These areas provide loafing opportunities for gulls and small mammals that inhabit rock crevices and small vegetated areas that have opportunistically grown up along the shoreline.

The PN intake forebay and PN discharge channels provide both loafing and foraging habitat for a variety of waterbird species. These areas remain ice-free throughout the winter and offer shelter from Lake Ontario during inclement weather.

2.3.5.6.2 Terrestrial Animal Species at Risk

Terrestrial animal species at risk have been recorded at the PN site (Beacon, 2017a, 2017b, 2018, 2019, 2020b; OPG, 2016b; TRCA, 2009a, 2014), along with their federal and provincial ranking updated to 2022, and are presented in Table 2.15. The list includes observations from the 2009 to 2013 TRCA inventories, and results from the OPG PN Site Biodiversity Program annual reports from 2016 to 2020, as well as earlier referenced observations for the area. OPG inventories include incidental observation, migrants and residents and therefore species listed in Table 2.15 are not necessarily breeding within the PN site. One reptile species and six bird species (Table 2.15) with a provincial ranking of threatened or special concern have been recently or historically recorded at the PN site.

Table 2.15: Terrestrial Animal Species at Risk Observed within the PN Site

Scientific Name	Common Name	Federal Species at Risk Status	Provincial Ranking	Most Recent Year Observed
Amphibians and Reptiles				
Emydoidea blandingii	Blanding's Turtle	Endangered	Threatened	2006

Scientific Name	Common Name	Federal Species at Risk Status	Provincial Ranking	Most Recent Year Observed
Birds				
Chaetura pelagica	Chimney Swift	Threatened	Threatened	2020
Chordeiles minor	Common Nighthawk	Threatened	Special Concern	2010
Dolichonyx oryzivorus	Bobolink	Threatened	Threatened	2006
Hirundo rustica	Barn Swallow	Threatened	Special Concern	2020
Ixobrychus exilis	Least Bittern	Threatened	Threatened	2020
Riparia riparia	Bank Swallow	Threatened	Threatened	2008

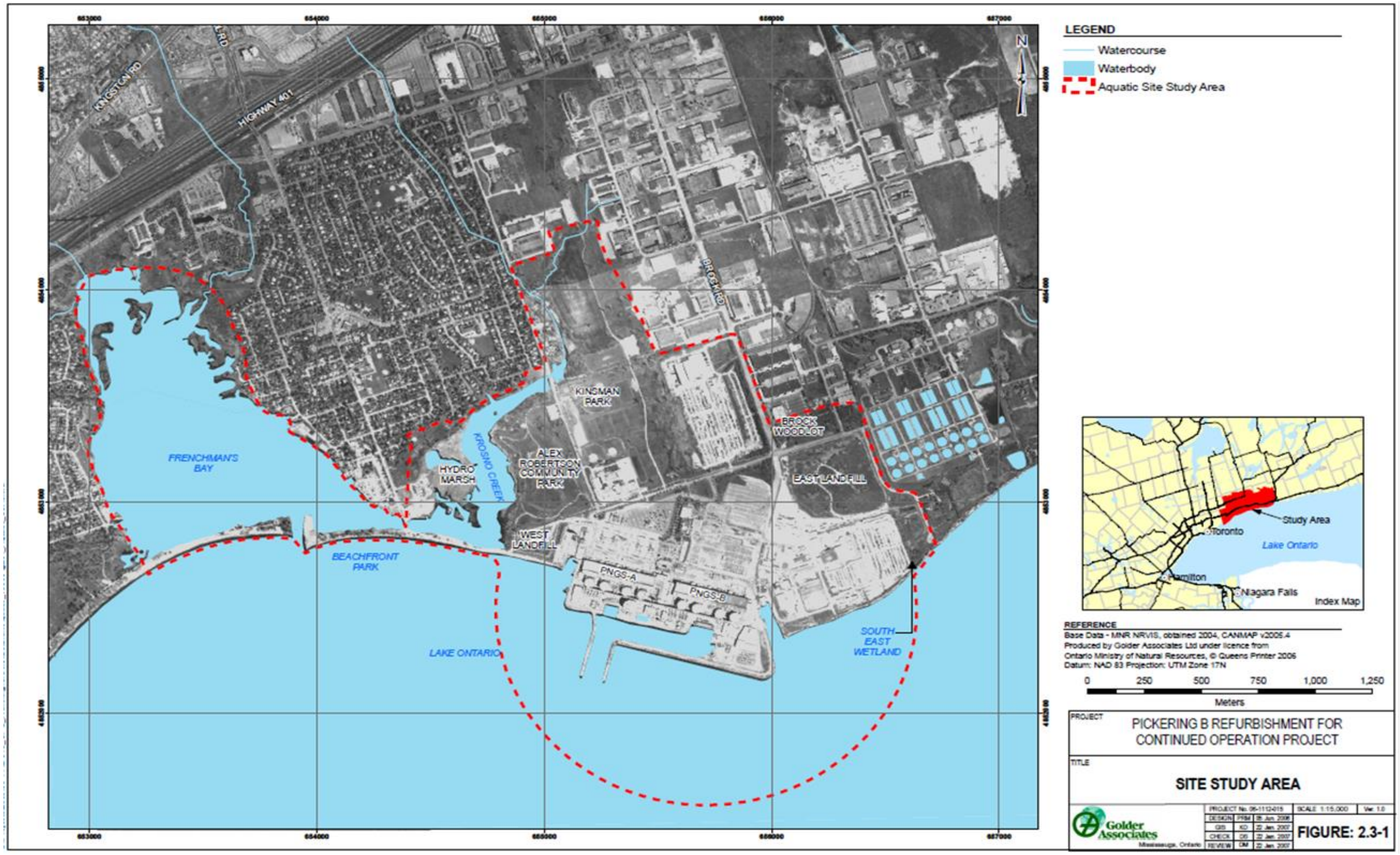
Notes:
The Provincial Species at Risk in Ontario List, Federal List of Wildlife Species at Risk (Schedule 1 of the Species at Risk Act (SARA)), and COSEWIC list are frequently revised.
Sources: (Beacon, 2017a, 2017b, 2018, 2019, 2020b; OPG, 2016b)

OPG initiated an annual PN Site Biodiversity Program in 2016, which was intended to become a long-term monitoring tool that can show changes in diversity. Monitoring is conducted annually for amphibians, breeding birds, bats and species at risk birds. Incidental observations are also recorded. Prior to 2015, OPG has maintained a species list for the PN site which incorporates the results of long-term monitoring programs conducted by TRCA (OPG, 2016b). Common Nighthawk, Bobolink and Bank Swallow have not been observed in the long-term monitoring programs and therefore there is over a decade of survey data to support that these bird species are not expected to be present at the PN site. Future ERAs will consider the potential of increased presence of Bank Swallow if the PN Fixed Face Earthen Embankment becomes utilized by Bank Swallows.

A search of the Ministry of Natural Resources and Forestry (MNRF) Natural Heritage Information Centre (NHIC) website was conducted in November 2022 for the presence of SAR within the Terrestrial Study Area. Eight NHIC grids overlapping with and adjacent to the PN site and Frenchman's Bay were reviewed: 17PJ5353, 17PJ5453, 17PJ5553, 17PJ5653, 17PJ5352, 17PJ5452, 17PJ5552 and 17PJ5652. The search identified the following terrestrial bird or mammal species with threatened or endangered status: Barn Swallow, Blanding's Turtle, Bobolink, Eastern Meadowlark, Golden-winged Warbler (*Vermivora chrysoptera*), Henslow's Sparrow (*Ammodramus henslowii*), Least Bittern, and Western Chorus Frog (*Pseudacris maculata*, Great lakes-St. Lawrence-Canadian Shield population). All but four of the species have been recently or historically observed. Western Chorus Frog, Henslow's Sparrow, Eastern Meadowlark and Golden-Winged Warbler have not been identified in species inventories at the PN site (Beacon, 2017a, 2017b, 2018, 2019, 2020b; OPG, 2016b). Given the lack of suitable habitat for these four species, it is not expected that they are present/breeding onsite and therefore are not included in Table 2.15 as species at risk.

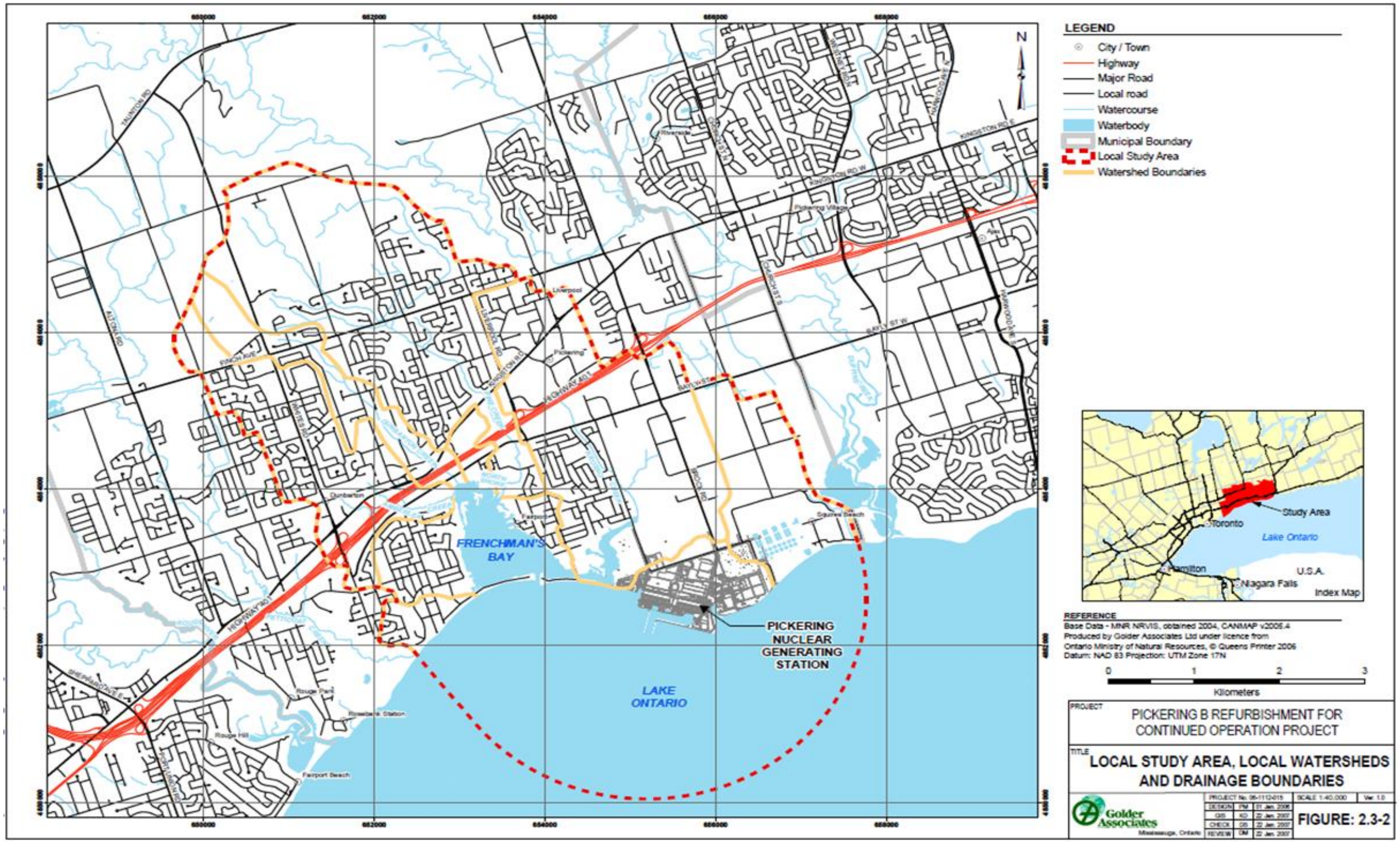
2.3.6 Aquatic Communities

This section describes existing aquatic communities focusing on the SSA and LSA (Figure 2.19: Aquatic Site Study Area and Figure 2.20: Aquatic Local Study Area), as these two areas encompass the larger area in which direct effects of the PN site may be measurable. The RSA, which encompasses areas of Lake Ontario outside of the LSA, is discussed in terms of regional fish and invertebrate populations that migrate into the SSA and LSA. More detailed descriptions of site, local and regional aquatic environments and the aquatic communities therein are provided in (Golder, 2007c).



Source: (Golder, 2007c)

Figure 2.19: Aquatic Site Study Area



Source: (Golder, 2007c)

Figure 2.20: Aquatic Local Study Area

2.3.6.1 Periphyton, Phytoplankton and Zooplankton Communities

Plankton communities in the vicinity of the PN site are highly variable and have undergone significant changes over the past 30 years that are not related to PN site activities. For example, changes to nutrient loadings, fluctuating populations of pelagic planktivores, colonization by the filter feeding zebra mussel and introduction of exotic zooplankton predators have altered the plankton community structure of Lake Ontario. Therefore, the use of historical information, prior to the mid-1970s, in describing current conditions may be of limited use based on the ecosystem changes in Lake Ontario.

Since the 1970s, phytoplankton biomass has declined in Lake Ontario presumably due to phosphorus reduction programs and the colonization of zebra mussels (Environment Canada et al., 1998). Diatoms dominate the overall phytoplankton community in diversity and biomass. In summer, during stable stratified conditions, phytoplankton communities in Lake Ontario shift away from diatoms to include substantial contributions to biomass by chlorophytes, cyanophytes and dinoflagellates (Barbiero and Tuchman, 2001). Decreases in the densities of several major algal groups, including diatoms, chlorophytes and cryptophytes, have contributed to the overall decrease in algal density observed in nearshore algal communities along the northshore of Lake Ontario (Winter et al., 2012, p. 2).

The zooplankton community in Lake Ontario is dominated by a small number of species and the current community composition appears to have been stable since the 1960s (Barbiero and Tuchman, 2001; Lampman and Makarewicz, 1999). The total crustacean densities and species richness are generally higher during the summer than in the spring. Structuring of the zooplankton community is affected by the intense planktivory particularly by alewives. Dominant zooplankton groups include crustaceans, primarily cyclopod copepods, along with cladocerans, *Bosmin*a and *Daphnia* (Barbiero et al., 2001).

Periphyton is benthic algal material. The periphyton community near PN are dominated by the filamentous algae *Cladophora glomerata* that grows attached to solid substrata and forms dense growths that are periodically detached by waves and wash ashore. *Cladophora* growth is limited by availability of phosphorous and light penetration (substratum availability). Phosphorous reduction programs in Lake Ontario initially resulted in a reduction in *Cladophora* productivity. However, habitat availability for *Cladophora* and overall productivity have increased since the 1990s, due to reduced algal growth and colonization of the lake by filter feeding zebra and quagga mussels which have reduced water turbidity and offset reductions (Auer et al., 2010; Higgins et al., 2008).

2.3.6.2 Benthic Invertebrates

The benthic community of the north shore of Lake Ontario is characteristic of the unstable, relatively severe conditions typical of the exposed coast. Small crustaceans (especially the benthic amphipod, *Diporeia* spp.) and worms (oligochaetes) have historically dominated the open water benthic communities of Lake Ontario. Benthic community studies conducted from 1976 to 1978, indicated that the community was dominated by oligochaetes and chironomids, and contained significant numbers of amphipods, molluscs and ostracods (Lush 1981, cited in

(Golder, 2007c)). Representatives of the more environmentally sensitive groups such as Ephemeroptera and Trichoptera were rare. Most of the dominant taxa had higher abundances at sites within or close to the PN U1-4 thermal plume than at reference sites. Diversity was generally higher in the spring/fall than in the summer/winter seasons. The diversity of the invertebrate community at sites with a depth of 6 and 10 m were influenced by the thermal plume and diversity was significantly lower than for the reference sites. This observation was attributed to an increase in the relative abundance of certain species and not to a reduction in species numbers. No differences in diversity were noted at the 1 m sites, presumably due to the exposed conditions that masked plume effects. Gastropods and bivalves had low relative abundances due to wave abrasion and/or unsuitable substrates at shallow locations. Abundance of chironomids, amphipods and oligochaetes increased in the vicinity of the discharge channels (1 m sites) where the alga, *Cladophora*, was present.

More recently, zebra mussels and quagga mussels have colonized the nearshore areas in the vicinity of PN and are now very abundant. Benthic organisms which have possibly been negatively affected by zebra and quagga mussels' colonization in nearshore areas of the lake include *Diporeia* spp., oligochaetes, sphaerid clams, and unionid clams (Golder, 2007c).

The aquatic macroinvertebrate community in Durham Region wetlands was studied as part of a 6-year coastal wetland monitoring project (EC, 2009a). Data for fifteen Durham Region coastal wetlands, collected between 2002 and 2007, were compiled and biotic communities were compared. Wetlands at or in the vicinity of the PN site that were included in the study included Hydro Marsh, Frenchman's Bay and Duffins Creek Marsh. The study used Indices of Biological Integrity (IBI) to assess and compare wetland conditions. The IBI values for macroinvertebrate communities were derived using measures for richness (number of Ephemeroptera and Trichoptera genera and total number of families), and relative abundance (percent crustacea and mollusca, percent tricoptera, and percent diptera). Over the study period, most Durham Region coastal wetlands were on average in "good" or "fair" condition. Hydro Marsh was notable as "poor", Frenchman's Bay Marsh was "fair" and Duffins Creek Marsh was "good" (EC, 2009b). Overall, macroinvertebrate communities in Durham Region were considered to be in poorer condition relative to other Lake Ontario wetlands.

2.3.6.3 Fisheries

More than 90 species of fish are known to inhabit Lake Ontario. Almost all of these species make use of nearshore waters of the lake for spawning, rearing, feeding, and migrations. Many of these species rely on habitats contained within coastal marshes, embayments and estuaries. Examples of these habitats within the SSA and LSA include Hydro Marsh, Frenchman's Bay and the Mouths of the Rouge River and Duffins Creek.

Fish species at risk that have been recorded at the PN site, along with their federal and provincial ranking, are listed in (OPG, 2016b). The list includes observations from the 2016 to 2020 inventories as well as earlier referenced observations for the area. Three fish species at risk (Table 2.16) with a provincial (updated to July 21, 2020) or federal ranking of threatened, endangered or extinct were recorded at the PN site. Atlantic Salmon were observed within the area as recently as 2020, one was impinged in April 2020 (OPG, 2021f). The last previous observation was in 2010. The Atlantic Salmon Lake Ontario Population is listed as extinct federally and provincially. Atlantic Salmon found in Lake Ontario are likely individuals from the Atlantic Salmon stocking program and are not considered individuals of the native Lake Ontario Population. American Eel was observed every year in the annual impingement monitoring programs between 2016-2020 (OPG, 2017d, 2018f, 2019c, 2020c, 2021f).

Lake sturgeon are generally uncommon in the main lake and have not been reported in the vicinity of PN since 2005 (OPG, 2012c; TRCA, 2022). Lake Sturgeon typically inhabit the cool bottom waters of lakes and large streams, preferring sand and silt substrates (Holm et al., 2021). Spawning occurs in fast-flowing streams during the spring. Historically, Lake Sturgeon spawning was reported in the Don River, Ganaraska River, Trent River, Napanee River (Goodyear et al., 1982). Presently the lower Niagara River and lower Trent River support low and very low populations of both adult and juvenile Lake Sturgeon, respectively (COSEWIC, 2017). Considering that the vicinity of PN is not conducive to habitat preferences for Lake Sturgeon, its presence is considered to be a historical observation for the PN site.

Impingement monitoring in 2013 identified Silver Shiner (*Notropis photogenis*) and Spotted Gar (*Lepisostreus oculatus*), which both have a provincial status of threatened in the Species at Risk in Ontario List, and Silver Shiner are listed as Threatened and Spotted Gar as Endangered under SARA Schedule 1. However, the reported range of these species does not overlap central Lake Ontario. Silver Shiner has been reported in Western Lake Ontario, and Spotted Gar in the Bay of Quinte region in eastern Lake Ontario. Both species habitat preferences are creeks and streams rather than large lakes. The presence of these species in impingement samples is considered questionable and these prior records are deemed to be misidentifications.

OPG reported three Silver Shiners impinged in November 2013; however, no photographs or specimen samples were collected and therefore the identification could not be confirmed (OPG, 2014a). The 2013 observation was the first (and only) report of Silver Shiner at PN since sampling commenced in 2003, which supports the assumption that the 2013 specimen was a misidentification. Although known to occur in certain western Lake Ontario tributaries, Silver Shiners typically inhabit cool to warm, clear waters of streams. There was no explanation in the report of the anomalous Spotted Gar impinged in March 2013 (OPG, 2014a). A single photo of the reported Spotted Gar did not yield a conclusive identification and there remains a high potential that this individual was either the more common Longnose Gar, or a Florida Gar. OPG has requested the identification of other potential Spotted Gar to the Royal Ontario Museum and in those cases the identification was confirmed as Florida Gar.). Spotted Gar is one of the rarest fish in Canada (Holm et al., 2021). Populations occur in three coastal wetlands in Lake Erie: Long Point Bay, Point Pelee National Park, and Rondeau Bay. Single specimens have been recorded in Lake Ontario in Hamilton Harbour and East Lake (Lake Ontario) and an unconfirmed historical occurrence from the upper St. Lawrence River, near Kingston (COSEWIC, 2015). As such, Silver Shiner and Spotted Gar have not been listed in Table 2.16.

Table 2.16: Fish Species at Risk Observed within the PN Site Area

Scientific Name	Common Name	Federal Species at Risk Status	Provincial Ranking	Most Recent Year Observed
Fish				
Acipenser fulvescens	Lake Sturgeon *	Threatened	Endangered	2005
Anguilla rostrata	American Eel	Threatened	Endangered	2020
Salmo salar	Atlantic Salmon **	Extinct	Extinct	2020

Notes:
The Provincial Species at Risk in Ontario List, Federal List of Wildlife Species at Risk, Schedule I and COSEWIC list are frequently revised.
* Lake Sturgeon are generally uncommon in the main lake and have not been reported in the vicinity of PN since 2005. Considering that the vicinity of PN is not conducive to habitat preferences for Lake Sturgeon, its presence is considered to be a historical observation for the PN site.
** Atlantic Salmon (Lake Ontario Population) is listed as extinct. Atlantic salmon found in Lake Ontario are likely individuals from the Atlantic Salmon stocking program and are not considered to represent a native Lake Ontario Population.
Sources: (OPG, 2012c, 2016b, 2021f; TRCA, 2022)

The fish community may be divided into resident and migratory species. Migratory species are only seasonally present in the Lake Ontario nearshore, these include pelagic fishes such as Rainbow Smelt, Alewife and Brown Trout which make seasonal spawning migrations into the nearshore zone, including entering the discharge channels and the intake forebay of PN (when FDS is not present); and inshore fishes which occupy coastal marshes and river mouth habitats and enter the nearshore zone when water temperature and velocity conditions are favourable. In the case of the discharge channels, the warmer discharge water provides unique opportunities for fish and invertebrates, resulting in concentrated foraging opportunities. Table 2.17 lists resident and migratory fish species which have been observed within the site and local study areas.

Table 2.17: Common and Scientific Names of Resident and Migratory Fish Species at PN (Golder, 2007c)

Resident Fish Species		Migratory Fish Species	
Common Name	**Scientific Name**	**Common Name**	**Scientific Name**
Longnose Gar	*Lepisosteus osseus*	**Sea Lamprey**	*Petromyzon marinus*
Bowfin	*Amia calva*	Lake Sturgeon	*Acipenser fulvescens*
American Eel	*Anguilla rostrata*	**Alewife**	*Alosa pseudoharengus*
Gizzard Shad	*Dorosoma cepedianum*	Lake Chub	*Couesius plumbeus*
Goldfish	*Carassius auratus*	**Emerald Shiner**	*Notropis atherinoides*
Common Carp	*Cyprinus carpio*	Spottail Shiner	*N. hudsonius*
Common Shiner	*Luxilus cornutus*	Longnose Sucker	*Catostomus catostomus*
Golden Shiner	*Notemigonus crysoleucas*	**White Sucker**	*C. Commersoni*
Mimic Shiner	*N. Volucellus*	Redhorse Sucker	*moxostoma spp.*
Bluntnose Minnow	*Pimephales notatus*	**Rainbow Smelt**	*Osmerus mordax*
Fathead Minnow	*P. promelas*	Lake Herring (Cisco)	*Coregonus artedi*
Longnose Dace	*Rhinizchethys cataractae*	**Lake Whitefish**	*C. clipeaformis*
Quillback	*Carpiodes cyprinus*	Pink Salmon	*Oncorhynchus gorbuscha*
Black Bullhead	*Amejurus melas*	**Coho Salmon**	*O. kisutch*
Brown Bullhead	*A. nebulosus*	**Rainbow Trout**	*O. mykiss*
Channel Catfish	*Ictalurus punctatus*	**Chinook Salmon**	*O. tshawytscha*
Stonecat	*Noturus flavus*	Round Whitefish	*Prosopium cylindraceum*
Northern Pike	*Esox lucius*	**Atlantic Salmon**	*Salmo salar*
Trout-perch	*Percopsis omiscomaycus*	**Brown Trout**	*Salmo trutta*
Brook Silverside	*Labidesthes sicculus*	Brook Trout	*Salvelinus fontinalis*
Brook Stickleback	*Culaea inconstans*	Splake	*S. fontinalis X S. namaycush*
White Perch	*Morone americana*	**Lake Trout**	*S. namaycush*
White Bass	*M. chrysops*	**Threespine Stickleback**	*Gasterosteus aculeatus*
Rock Bass	*Ambloplites rupestris*	Mooneye	*Hiodon tergisus*
Pumpkinseed	*Lepomis gibbosus*	**Round Goby**	*Neogobius melanostomus*
Bluegill	*L. macrochirus*		
Smallmouth Bass	*Micropterus dolomieu*		
Largemouth Bass	*M. salmodies*		
White Crappie	*Pomoxis annularis*		
Black Crappie	*P. nigromaculatus*		
Johnny Darter	*Etheostoma nigrum*		
Yellow Perch	*Perca flavescens*		
Logperch	*Percina caprodes*		
Walleye	*Sander vitreus*		
Freshwater Drum	*Aplodinotus grunniens*		

Resident Fish Species		Migratory Fish Species	
Common Name	**Scientific Name**	**Common Name**	**Scientific Name**
Slimy Sculpin	*Cottus cognatus*		
Mottled Sculpin	*C. bairdi*		

Notes:
Data derived from LGL Limited, 1992; Toronto and Region Conservation Authority, 1999; Golder Associates, 2000, as cited in (Golder, 2007c).
Fish species in bold font have been identified during impingement monitoring for PN for the 5-year period from 2016 to 2020 (OPG, 2017d, 2018f, 2019c, 2020c, 2021f).

Spawning and Rearing Habitats

On a local level, the exposed shoreline of Lake Ontario provides rocky substrates for Lake Trout and Round Whitefish spawning in the shallow nearshore waters east of PN. Both east and west of PN, the Lake Ontario nearshore areas support broadcast spawning by Emerald Shiner. Juvenile habitat for Lake Trout, Round Whitefish and Emerald Shiner exists both east and west of PN as well. The Rouge River mouth and Duffins Creek contains spawning and juvenile habitats for Northern Pike, Smallmouth Bass and Emerald Shiner and juvenile habitat for White Sucker. Frenchman's Bay may provide spawning and juvenile habitat for Smallmouth Bass, Northern Pike, White Sucker and Emerald Shiner.

Spawning habitat for Smallmouth Bass, Northern Pike and Emerald Shiner exists within the SSA. Smallmouth Bass spawning and nest-building occur within the PN discharge channels. The shoreline is a high energy habitat, due to the effects of Lake Ontario wave action and fish species are not likely to use it as spawning habitat with the possible exception of Emerald Shiner. Northern Pike and Emerald Shiner may use Hydro Marsh as spawning habitat. The SSA also provides rearing habitats for immature stages of some species, such as Smallmouth Bass (PN discharge channels, the armoured shoreline, and Hydro Marsh), Round Whitefish (PN U1-4 discharge channel and the armoured shoreline), White Sucker (PN discharge channels) and Emerald Shiner (the armoured shoreline).

An exploratory Round Whitefish spawning population assessment project was conducted at three locations (Pickering, Darlington and Peter Rock) along the north central shoreline of Lake Ontario during late November and early December, 2014 (MNRF, 2015). Round Whitefish were collected from each location with the objective to obtain detailed biological attribute information from the spawning population of fish. The Round Whitefish ranged from 3 to 26 years of age. Fifty-five percent of the fish caught were male. Gonad condition indicated that the netting dates in late November and early December, bracketed peak spawning time for Round Whitefish.

As part of this work, Round Whitefish collected during spawning at the three locations were subjected to genetic analysis to determine whether local meta-populations are discernable. This would be relevant to interpretation of potential effects on Round Whitefish at the population level. The studies have not produced any evidence for discrete meta-populations among Round

Whitefish from the different sampling locations. Instead, the studies supported the presence of a single panmictic population of Round Whitefish in Lake Ontario (MNRF, 2016).

Foraging Habitats

Foraging opportunities may be seasonal and dependant on local conditions. For example, Lake Trout can only forage in the nearshore zone when colder water temperatures exist due to the season or to wind-driven upwellings of colder lake water. Coldwater species such as Lake Trout and Round Whitefish, winter in Lake Ontario and are not likely to feed within the river mouth and marsh habitats. Warm and coolwater species such as Smallmouth Bass, Northern Pike, Walleye, White Sucker and Emerald Shiner, likely use the mouth of the Rouge River, Duffins Creek mouth/marsh habitat, and Frenchman's Bay as foraging habitat.

Each of the habitats within the SSA provide foraging habitats for at least some fish species. Piscivores, such as Smallmouth Bass, Northern Pike, Walleye and Lake Trout have been observed in the intake forebay and may feed on schools of baitfish. Round Whitefish and White Sucker may feed on bottom dwelling invertebrates associated with aquatic vegetation and the variety of substrates found within the forebay. The armoured shoreline may provide foraging habitat for many fish species including Northern Pike, Walleye and Lake Trout which are attracted to schools of small planktivorous fishes such as the Emerald Shiner that are common in the shallows along the breakwalls. Smallmouth Bass may use the protective cover and foraging opportunities provided in the spaces among the armour, and White Sucker and Round Whitefish may feed on benthic invertebrates in the shallow water adjacent to the armoured shoreline.

Impingement monitoring for the 5-year period from 2016 to 2020 identified 48 species of fish which may occupy the intake forebay (OPG, 2017d, 2018f, 2019c, 2020c, 2021f). Of these species, the most commonly impinged fish species are Alewife, Round Goby, Three-Spine Stickleback, Gizzard Shad, Emerald Shiner, and Rainbow Smelt. Entrainment and impingement effects are discussed in Section 4.4.4.

Forty-two of the fish species identified during impingement monitoring from 2016 to 2020 are included in Table 2.17 (as shown in bold font). The remaining six species identified during impingement monitoring are not typically considered to be resident or migratory fish species of Lake Ontario. Four of the six species were identified only once during the monthly monitoring events over the 5-year period (Unid, Unid-Sucker Species, American Brook Lamprey, Silver Redhorse). Two of the six species were identified twice (Unid-Salmonids and Northern Sucker. Round Goby, an invasive species in Ontario waters, was identified in all impingement studies.

Migration and Overwinterings

Walleye, Lake Trout, Round Whitefish, White Sucker and Emerald Shiner may follow the shoreline on regional or local migrations to and from deeper water. Smallmouth Bass and Northern Pike are more closely associated with coastal marshes and embayments but may migrate between those habitats by following the Lake Ontario shoreline. Migrations into Duffins Creek mouth may include spawning runs of Northern Pike, and White Sucker in the spring and

Brown Trout and introduced Atlantic Salmon in the fall, movements between protected warmwater habitats, seasonal foraging movements and movements in response to wind-driven water temperature changes. Smallmouth Bass, Northern Pike, White Sucker and Emerald Shiner migrate into, between or among the sheltered warmwater habitats along the shores of Lake Ontario, including the Duffins Creek mouth.

Winter habitats for Walleye, Lake Trout, Round Whitefish, White Sucker and Emerald Shiner are found in the nearshore waters of Lake Ontario in the LSA. White Suckers are tolerant of a wide range of water temperatures and are year-round inhabitants of the nearshore zone, and Lake Trout and Round Whitefish occupy nearshore areas when temperatures permit, throughout the year. Overwintering habitats may exist in Duffins Creek for Smallmouth Bass, Northern Pike and Emerald Shiner and in Frenchman's Bay for Smallmouth Bass, Northern Pike, Walleye, White Sucker and Emerald Shiner. Walleye and White Sucker may also migrate to Duffins Creek during the winter. Walleye are attracted by the thermal plume(s) during winter. Smallmouth Bass and Northern Pike are more likely to overwinter within coastal marshes and, possibly, in the PN discharge and intake channels. Emerald Shiner makes an offshore shift with the onset of winter but is present in the nearshore zone at other times of the year.

2.3.7 Human Land Use

Aspects of regional, local and site human land uses have been presented in the Pickering B Refurbishment EA (SENES, 2007b) and the Human Health TSD (SENES, 2007c). In this section, current land uses, agricultural production, water supply and recreational fishing are summarized.

2.3.7.1 Review of Durham Region and City of Pickering Land Use

PN is located in the Region of Durham, City of Pickering, on the north shore of Lake Ontario. It is approximately 21 km west southwest of Oshawa and approximately 32 km east of downtown Toronto. The Region of Durham and the City of Pickering have both urban and rural land uses. In general, the urban uses in the Region of Durham parallel the shoreline of Lake Ontario in the communities of Pickering, Ajax, Whitby, Oshawa and Clarington. The rural uses are in the northern portion of the municipality in the communities of Brock, Scugog and Uxbridge. The urban land uses in the City of Pickering, including residential, commercial and employment, are generally located south of 3rd Concession along Lake Ontario. The rural uses, including agricultural uses and rural hamlets, are generally located north of 3rd Concession.

PN is part of the Brock Industrial Neighbourhood, in the City of Pickering, immediately east of the Bay Bridges Neighbourhood, south of Highway 401, west of the Town of Ajax and north of Lake Ontario. The land use surrounding PN is largely urban, including industrial, residential and parkland. Duffins Creek Water Pollution Control Plant is located to the east of the PN site, and several marinas are located to the west of the PN site along Lake Ontario. Frenchman's Bay and Hydro Marsh (class 2 wetlands) are located approximately 1.5 km to the west and Duffins Creek Marsh (class 3 wetland/ environmentally significant area/ area of natural and scientific interest) is located approximately 2.5 km to the east.

PN is approximately 240 ha in size with a continuous landscaped buffer paralleling all adjacent municipal roads. PN is fenced and access is restricted and controlled by OPG. There is a 914 m exclusion zone around PN. This exclusion zone limits the type of uses that can occur within its confines. The exclusion zone is predominantly owned by OPG. These lands are primarily used for industrial purposes related to electricity generation. Two public outdoor recreation parks, Alex Robertson Community Park and Kinsmen Park, are located approximately 600 m northwest of PN U1-4, on lands leased by the City of Pickering.

OPG has made significant biodiversity improvements at Alex Robertson Park since 2000, including planting more than 14,000 trees and shrubs along with 1,800 native wildflowers.

2.3.7.2 Agricultural Production

An inventory of Ontario agricultural data was completed for the 2018 Pickering Nuclear Radiological Environmental Monitoring Program site specific survey (OPG, 2018d) using data from the 2016 Census of Agriculture conducted by Statistics Canada. The total area of land used for fruits, vegetables and potatoes in Ontario was estimated at 84,299 ha (843 km^2), which has increased by 4.8% comparing to the data from the 2011 Census of Agriculture. Of that total, 23.8% is used for fruit production, 59.2% is used for vegetable production and 17% is used for potato production. Assuming that agricultural production is uniform across Ontario, the total land used for fruit, vegetable and potato production within a 30 km radius semi-circle centered at PN was estimated to be 336 km^2, 837 km^2 and 240 km^2, respectively. Fruit, vegetable and potatoes production from within the 30 km radius semi-circle was estimated to be 4.5×10^8 kg, 2.1×10^9 kg and 5.9×10^8 kg, respectively.

2.3.7.3 Water Supply

Water supplies from four municipal water supply plants (WSP) are included in the PN EMP: the Ajax and Whitby WSPs situated east of PN, and J.F. Horgan and R.C. Harris WSPs situated southwest of PN. The water intake for the Ajax WSP located approximately 6.5 km east of the PN site is the nearest of the four WSPs to the PN site. All four WSPs obtain their water from Lake Ontario. The water supply for the City of Pickering and the Town of Ajax is provided primarily from the Ajax WSP which services a population of 211,448. The more rural areas of Durham are supplied by individual water supply systems from either surface water intakes or ground water wells. The F.J. Horgan WSP services Scarborough and sells water to the York Region. The R.C. Harris WSP services eastern and central Toronto and also sells water to the York Region.

Table 2.18 summarizes the offshore distance and depth of the WSP intakes, WSP capacities, populations served and distance of the intakes from the PN site for each of the PN EMP WSPs, recommended for use in public dose calculations (OPG, 2018d). Compared to the previous site specific survey review, the capacities have not changed while the estimated populations served have increased by 6.8% for Ajax WSP and by 0.5% for Whitby WSP. Also, the intake depth for Whitby WSP has been adjusted slightly from 15 m to 16 m.

Table 2.18: Water Supply Plant Information (OPG, 2018d)

Location	Distance of Intake from Shore (m)	Intake Depth (m)	Capacity (m^3/day)	Population Served[b]	Estimated Distance of Intakes from PN (km)
R.C. Harris WSP	2,300	15	950,000	1,500,000	21.7 km SW
F.J. Horgan WSP	3,200	9	800,000	2,000,000	11.3 km SW
Ajax WSP	2,506	18[a]	163,500	211,448	6.5 km E
Whitby WSP	1,710	16	118,000	122,022	12.3 km ENE

Notes:

[a] Ajax WSP's intake pipe is at a depth of 18 m, however the water is drawn in from an intake crib that is 13.5 m below the lake surface.

[b] This is an estimate as the WSPs feed into an integrated water distribution network.

2.3.7.4 Recreational Fishing

Recreational fishing near the PN property is popular among local residents, but is not a widespread activity among people living in the study area. Results from a recreational fisheries survey undertaken by OPG in the fall of 1999 indicated that most recreation fishing activity nearest the PN property was shore angling rather than boat angling (SENES, 2007b). Of the shore angling sites, Frenchman's Bay was the most popular. At PN, Smallmouth Bass is targeted the most. At Frenchman's Bay salmon and trout were most commonly targeted but Largemouth Bass and Common Carp were most commonly caught. At the Rouge River, west of the PN site, the most prevalent catch was common carp. An online search was done for recent creel studies in the PN area during the 2018 Pickering Nuclear Site Specific Survey (OPG, 2018d), including the MNRF and the TRCA websites. However, no new studies were identified with relevant information on time spent fishing and fish consumption for the Sport Fisher located near PN.

2.3.8 Population Distribution

The estimated population in Durham Region in 2018 was 683,600 (DRHD, 2019). The Durham Region population increased by 13% between 2008 and 2018. The aging of the population is apparent with growth occurring in ages 55 and older. In particular, seniors 90 years and older had the highest population growth in Durham Region with an overall increase of 114%. The largest increase occurred in Pickering where the population of seniors 90 and older almost tripled, going from just over 250 in 2008 to over 630 in 2018. The age groups with the largest decrease in population in Durham Region between 2008 and 2018 were adults 45 to 49 years (16% decrease) and adults 40 to 44 years (12% decrease). Overall population growth in Durham region between 2008 and 2018 was highest in Ajax (22%) and lowest in Brock (4%) while Scugog experienced a 1% drop in population size in the same period (DRHD, 2019).

The majority of residents in Durham region live in urban areas. Over 90% of the population in Pickering, Ajax, Oshawa and Whitby reside in urban areas, whereas, the townships of Brock, Scugog and Uxbridge represent the greatest percentage of the rural population in Durham. Urban/rural population trends for Durham indicate this trend will continue into 2031 (DRHD, 2015).

Based on Ontario Population Estimates (2018), children under the age of 15 comprised 17.6% of the population in 2018 in Durham Region, while young persons (aged 15-24), adults (aged 25-64) and older adults (aged 65+) comprised 13.3%, 54.4% and 14.8%, respectively (DRHD, 2019). Ontario Population Estimates (2018) indicate that the 55 to 59 age group is the largest age group for both males and females in Ontario and in Durham Region.

The most recent census data for the region are for 2016. A population of approximately 2.4 million reside within a 30 km radius of the PN site, based on 2016 census data shown in Table 2.19 (OPG, 2018d). The bulk of this population (approximately 82% or 2 million) resides west of the PN site, in the southwest to north-north-west sectors, while approximately 18% (0.4 million) reside east of the PN site in the north to east-north-east sectors. Areas south and east of the PN site (south-south-west to east) are occupied by Lake Ontario. Approximately 0.1% of this population (3,089) reside within a 0 to 2 km radius of the PN site, 8% of this population (199,821) reside within a 0 to 8 km radius, and 26% (621,410) reside within a 0 to 16 km radius of the PN site. Some of the changes that have occurred in the population distribution around the PN site since the last site-specific survey review, which used 2011 census data, are summarized below:

- The total number of people living within 8 km of PN has increased by 6%.
- Within 8 km of PN, populations in the NNE, ENE, WSW, WNW and NNW have increased by 74%, 241%, 44%, 10%, and 27%, respectively. Populations in the N, NE, SW, W and NW have decreased by 24%, 25%, 89%, 20% and 6%, respectively.
- Within 8 km of PN, the population is fairly evenly distributed around the station. Between 8.6% and 15% of the population live in each of the following wind sectors: N, NNE, NE, ENE, WSW, W, WNW, NW and NNW. Only 0.74% of the population (1,487 out of 199,821 residents) live SW of the station.
- The total number of people living within 30 km of PN has increased by 10%.
- Within 30km of PN, approximately 31% of the population lives WSW of the station and 25% live W of the station.

Table 2.19: Population Distribution Surrounding PN Based on 2016 Census Data

Direction	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
0-2 km	48	0	0	392	0	0	0	0	0	0	0	0	0	611	1,069	969	3,089
2-4 km	2,133	0	658	4,047	0	0	0	0	0	0	0	907	3,460	3,894	5,569	6,773	27,441
4-6 km	8,241	7,712	8,233	9,421	0	0	0	0	0	0	0	6,042	6,044	13,806	9,714	12,436	81,649
6-8 km	12,975	22,533	9,062	5,877	0	0	0	0	0	0	1,487	15,988	7,751	6,832	1,772	3,365	87,642
8-10 km	4,843	22,236	1,686	221	0	0	0	0	0	0	306	14,013	15,492	260	52	266	59,375
10-12 km	241	7,100	11,508	6,137	0	0	0	0	0	0	808	29,933	26,025	107	176	47	82,082
12-14 km	606	2,217	28,216	2,231	0	0	0	0	0	0	2,185	44,682	38,430	9,604	211	118	128,500
14-16 km	102	1,919	29,251	5,557	0	0	0	0	0	0	3,693	54,462	21,263	29,848	5,517	20	151,632
16-22 km	635	22,929	72,171	63,758	0	0	0	0	0	0	49,970	183,700	199,654	132,655	23,500	1,640	750,612
22-30 km	1,369	2,239	29,147	42,056	0	0	0	0	0	0	172,444	401,674	289,019	91,416	28,949	3,099	1,061,412
Total	31,193	88,885	189,932	139,697	0	0	0	0	0	0	230,893	751,401	607,138	289,033	76,529	28,733	2,433,434

Source: (OPG, 2018d)

3.0 Human Health Risk Assessment

3.1 Problem Formulation

3.1.1 Receptor Selection and Characterization

3.1.1.1 Receptor Selection

Human receptors are defined as on-site workers, contractors and visitors, as well as off-site members of the public.

3.1.1.1.1 On-site Non-Nuclear Energy Workers

On-site workers, contractors, and visitors are potentially exposed to environmental contaminants, both chemical and radiological, but these exposures are considered and controlled through the Health and Safety Management System Program and the Radiation Protection Program, and are not considered in the HHRA, as discussed below.

The Health and Safety Management System Program is designed to ensure the protection of employees, contractors and visiting members of the public. The program outlines a systems approach used to manage risks associated with activities, products and services of OPG Nuclear operations. Contractors are required to maintain a level of safety equivalent to OPG staff while working at an OPG workplace. Work at OPG is subject to safe work planning requirements where safety hazards are identified and mitigating measures are communicated through Pre-Job Briefings. Routine or planned work is governed by approved procedures and operating instructions (PROG-0010-R004) (OPG, 2018g).

The Radiation Protection Program is designed to ensure that doses for employees, contractors and visiting members of the public are below regulatory limits, and As Low As Reasonably Achievable, social and economic factors being taken into account (ALARA). Employee radiation doses are monitored to ensure they do not exceed exposure control levels that are below regulatory limits. Doses to visitors and contractors are also monitored. Only workers classified as Nuclear Energy Workers (NEWs) may perform radioactive work. Visitors are limited to non-radioactive work and escorted by a qualified NEW. Personal information is collected for the purposes of dose reporting (N-PROG-RA-0013 R011) (OPG, 2019d).

Because human exposures on the site are kept within safe levels through the Health and Safety Management System Program and Radiation Protection Program, on-site receptors are not addressed further in the HHRA. The focus of the HHRA is on off-site members of the public.

3.1.1.1.2 Members of the Public

Off-site members of the public are potentially exposed to low levels of airborne or waterborne contaminants. The potentially most affected off-site members of the public are defined as "critical groups". Potential critical groups are defined through the site-specific survey and used for dose calculations in the OPG Annual Environmental Monitoring Programs (EMP) Reports. The most recent site specific survey was completed in 2018 (OPG, 2018d), and concludes that the six potential critical groups identified in the 2012 site specific survey are still appropriate; however, the 2018 survey provides some updated critical group characteristics. The six potential critical groups are:

- C2 Correctional Institution
- Local Urban Residents
- Local Farms
- Local Dairy Farms
- Sport Fishers
- Off-site Industrial/Commercial Workers

These six potential critical groups are used for the exposure assessment for both radiological and non-radiological COPCs.

3.1.1.1.3 Indigenous Communities

Indigenous communities were considered in the selection of receptors for the HHRA. Information from engagement with Indigenous communities, councils and organizations gathered during preparation of the PN U5-8 Refurbishment EA (SENES, 2007e) did not indicate use of lands, water or resources for traditional purposes within the Local Study Area (defined for the PN U5-8 Refurbishment EA as extending approximately 10 km from PN). However, it is possible that individuals may carry out these activities in a limited fashion as these activities would be restricted by the urbanization, population density, and preponderance of private land in the area. Because of this, it was judged that any influence from PN on the health of Indigenous communities was likely to be bounded by the assessment for potential critical groups located much closer to PN who consume foods local to PN as part of their diet. For example, the farm receptors obtain a large fraction of their fruits, vegetables and animal produce locally, with the nearest location at 6 km from PN. While there may be dietary differences such as more wild game in the Indigenous diet, and more farm produce in the farm diet, both groups will have high local food intake fractions, and overall dietary intakes will be similar. Likewise, the Sport Fishers are assumed to obtain their entire fish diet from the PN outfall. It is expected that Indigenous communities would receive doses that are equal to or lower than those received by these potential critical groups.

OPG initiated engagement with the Williams Treaties First Nations in July 2021 to seek feedback on the list of Valued Ecosystem Components (VECs) that would be used in the 2022 PN ERA (discussed further in Section 4.1.1). OPG did not receive specific feedback on the current use of the lands, water or resources for traditional purposes, however, OPG plans to have ongoing discussions with the Williams Treaties First Nations to incorporate relevant information into future ERAs.

3.1.1.2 Receptor Characterization

The receptor characteristics used for the exposure assessment are described in Appendix E of the 2020 EMP Report (OPG, 2021c) and are presented below.

- The **C2** potential critical group consists of inhabitants at a correctional institute, located approximately 3 km NNE of the PN site. The C2 group obtains drinking water from the Ajax WSP and does not consume locally produced fruits or vegetables. The C2 resident is conservatively assumed to be at this location 100 percent of the time over at least one year.

- The **Industrial/Commercial** potential critical group consists of adult workers whose work location is close to the nuclear site. Members of this group are typically at this location about 23% of the time. They consume water from the Ajax WSP. The closest location for this group is about 1 km NNE of the site.

- The **Urban Residents** potential critical group consists of Pickering and Ajax area residents which surround the PN site (e.g., Fairport, Fairport Beach, Rosebank, Liverpool, Pickering Village, etc.). The members of this group mostly consume water from the Ajax WSP and also consume a diet composed in part of locally grown produce and some locally caught fish. Members of this potential critical group are also externally exposed to beach sand at local beaches (Beachpoint Promenade, Beachfront Park or Squires Beach).

- The **Farm** potential critical group consists of residents of agricultural farms (but not dairy farms) within a 10 km radius of the PN site. Members of this group obtain most of their water supply from wells but also a portion from the Ajax WSP. Members of this potential critical group consume locally grown produce and animal products. They are also externally exposed to beach sand at local beaches (Beachpoint Promenade, Beachfront Park, or Squires Beach).

- The **Dairy Farm** potential critical group consists of residents of dairy farms within a 20 km radius of the PN site. This group obtains most of their water supply from local wells. They also consume locally grown fruit and vegetables and locally produced animal products, including fresh cow's milk. Members of this potential critical group are also externally exposed to beach sand at local beaches (Beachpoint Promenade, Beachfront Park, or Squires Beach).

- The **Sport Fisher** potential critical group is comprised of non-commercial individuals fishing near the PN site outfalls, 0.5 km S of the PN site. Members of this group were conservatively assumed to obtain their entire amount of fish for consumption from the vicinity of the PN site and spend 1% of their time at the outfall location where atmospheric exposure occurs.

The receptors that are closest to the facility are the Sport Fisher, the Urban Resident, and the Industrial/Commercial Worker. Within each potential critical group three different age classes are defined: 0-5 years (infant), 6-15 years (child), and 16-70 years (adult), consistent with CSA N288.1. Site-specific receptor data were used for the exposure assessment, where available. Otherwise, default receptor characteristics such as body weight, inhalation rates, ingestion rates etc. were obtained from sources as outlined in CSA N288.6-12 (CSA, 2012). The radiological HHRA presents doses already reported in EMP reports from 2016 to 2020, using site-specific data from the 2018 site-specific survey (OPG, 2018d). For the non-radiological HHRA, site-specific data from the 2018 site-specific survey were used (OPG, 2018d).

As recommended by CSA N288.6-12, human health radiological risk assessments should follow the guidance of CSA N288.1. With exception of the drinking water intake rate for the 1-year-old infant, the intake rates are the mean intake rates from CSA N288.1. As discussed in (OPG, 2010c), the drinking water intake rate for a 1 year old infant is 0 kg/a since the 1 year old is assumed to only drink cow's milk; as recommended in CSA N288.1.

3.1.2 Selection of Chemical, Radiological, and Other Stressors

The PN facility emits chemical and radiological contaminants to air and water in the normal course of operations. Measurements and modeled concentrations of these contaminants in air and water taken from 2016 to the end of 2020 were screened against available screening benchmarks that are protective of human health to determine if any contaminants of potential concern (COPCs) required further study in the context of human health risk assessment. Where no data were available during the 2016 to 2020 period, older data were used. The potential for screening for COPCs in other environmental media is also discussed below.

3.1.2.1 Chemical COPCs in Air

The main sources of atmospheric emissions result from boiler chemical emissions and fuel combustion. Boiler treatment chemicals including hydrazine, morpholine and degradation products are used within the feedwater system to prevent corrosion in the boilers. These chemicals are released to the atmosphere through controlled boiler venting. Combustion emissions result from the Standby Gas Turbines, Auxiliary Power System Combustion Turbine Units, Auxiliary Power System Diesel Generators and minor sources. These systems release carbon monoxide, nitrogen oxides, sulphur dioxide, suspended particulate matter, trace volatile organic compounds, trace metals, and polycyclic aromatic hydrocarbons (PAHs).

3.1.2.1.1 Emission Summary and Dispersion Modelling Reports

ESDM reports for 2015 and from 2017 to 2020 were consulted to aid in chemical COPC selection for air (Golder, 2015; Ortech, 2019a, 2019b, 2020, 2021). In 2016, there were no modifications to the facility, and therefore the ESDM from 2015 was deemed applicable for that year (OPG, 2017e). The ESDM uses dispersion modelling to predict the maximum air concentration at the property line (Point of Impingement, POI) for each COPC.

Within the ESDM reports, a preliminary screening step is conducted to exclude negligible sources and negligible contaminants using Section 7 criteria in MECP Guideline A-10, *Procedure for Preparing an Emission Summary and Dispersion Modelling (ESDM) Report*. The sources and contaminants identified in the Emission Summary Table of the ESDM reports (2015 and 2017-2020) are the focus of the screening for air COPCs in this ERA.

Three operating scenarios are evaluated annually in the 2018-2020 ESDM reports. Scenario 1 represents a worst-case emission scenario, reflecting operations related to the production of electricity, and considers transitional operations associated with equipment start-up and shut-down (Ortech, 2021). Scenario 2 considers potential additive effects of nitrogen oxide emissions related to testing of emergency standby equipment. Scenario 3 considers operation of the auxiliary steam boilers as the primary heating source for the facility during the planned shut-down of nuclear power generation. The predicted concentrations resulting from Scenarios 1 and 2 were considered relevant for the time period bounded by this ERA.

In 2015 and 2017, the approved dispersion models described in the Appendix to O. Reg. 346 was used to estimate point of impingement (POI) concentrations based on a ½ hour averaging period for all air contaminants with exception of hydrazine, which was estimated using the AERMOD dispersion model to assess annual hydrazine concentrations. Due to the planned phase-out of the models in the Appendix to O. Reg. 346, the modelling of all contaminants transitioned to AERMOD in 2018, with POI concentrations provided for 1-hour, 24-hour, or annual averaging periods depending on the MECP POI limits.

Contaminant emissions were assessed within the ESDM reports by comparing POI concentrations estimated from emission rates to POI exposure benchmarks listed in the MECP publication, *Air Contaminants Benchmarks (ACB) List: Standards, guidelines and screening levels for assessing point of impingement concentrations of air contaminants* (the ACB list). The ACB list encompasses the air standards set out in O. Reg. 419/05, as well as a broader list of additional benchmarks further intended to aid facilities in preparing ESDM reports. Modelled POI concentrations were compared to respective MECP POI benchmarks with corresponding averaging periods, typically ½-hour, 24-hour, or annual averages. The air dispersion modelling results for nitrogen oxides from the testing of emergency standby equipment showed that the maximum predicted concentration was below the 1/2 -hour POI screening level of 1,800 µg/m^3.

For each calendar year, the applicable ESDM report demonstrated that the PN site was operating in compliance with s. 19 of O. Reg. 419/05.

3.1.2.1.2 HHRA Air Screening

For the purposes of this human health risk assessment, maximum predicted POI concentrations for each of the modelled parameters in Table 1 of the ESDM reports were compared to selected heath-based screening criteria following the hierarchy presented on Figure 3.1. Preferred primary guidelines consisted of the most conservative of the MECP Air Contaminant Benchmarks and the CCME Canadian Ambient Air Quality Standards (CAAQS). The CAAQS are available for PM2.5, ozone, sulfur dioxide, and nitrogen dioxide. If the limiting effect associated with the POI limit for a parameter on the ACB list is not health based (e.g., odour, effects on vegetation), and the parameter does not have a CAAQS, then a health-based value was selected from other sources. Secondary guidelines consisted of the MECP Ambient Air Quality Criteria (AAQC) (MECP, 2020). Tertiary guidelines consisted of the Effects Screening Levels (ESLs) established by the Texas Commission on Environmental Quality (TCEQ, 2016).

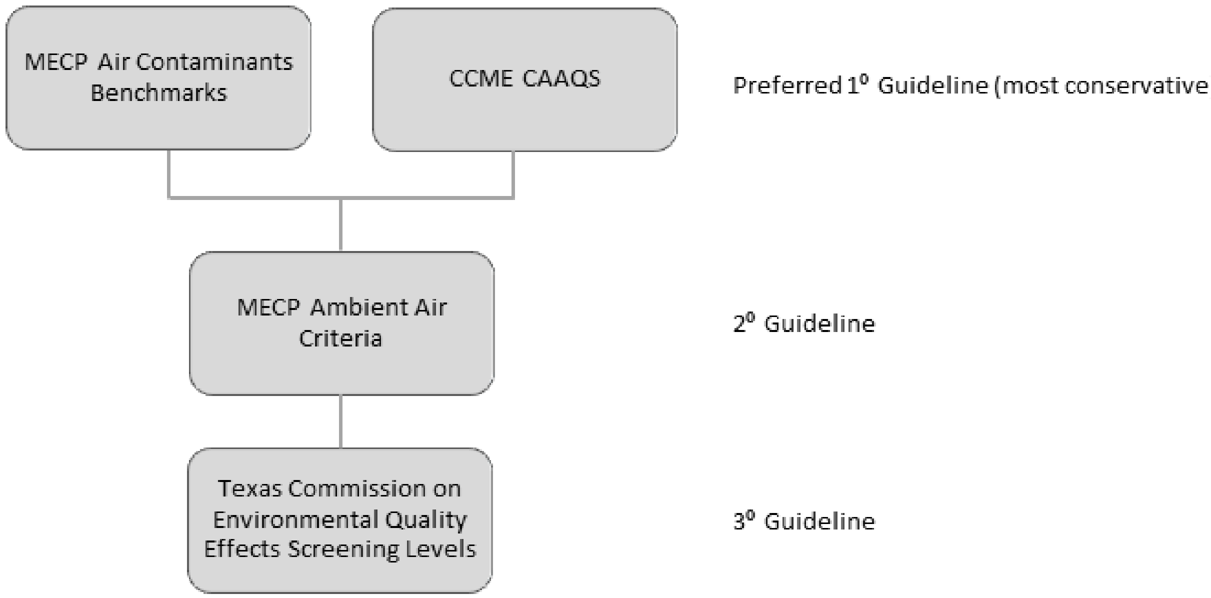


Figure 3.1: Screening Hierarchy for Chemical COPCs in Air for the HHRA

The HHRA screening of chemical COPCs in air is shown in Table A.1 (Appendix A). Modelled POI concentrations were directly compared to guidelines with the same averaging periods, or were adjusted to meet the timeframes of the relevant screening criteria using the formula described in Section 17 of O. Reg. 419/05.

Health-based screening values could not be identified for deuterium, ethylene, fluoride, methane, mineral spirits or total hydrocarbons. Deuterium, ethylene and methane were not assessed after 2015 or 2017 and have been considered to be present at *de minimus* levels (Golder, 2015). Due to limited information available concerning inhalation exposure to particulates of inorganic fluoride compounds (ATSDR, 2003), a screening value was not selected for fluoride for the HHRA. Mineral spirits did not exceed the MECP POI odour-based limit and were not assessed after 2015 (Golder, 2015). Total hydrocarbons were not assessed after 2015 and did not exceed their previously approved limit of 9.03 $\mu g/m^3$ (Golder, 2015).

With exception of nitrogen oxides, no other modelled POI concentrations exceeded the selected screening criteria in 2015 and from 2017 to 2020. Hydrazine was identified as a COPC in the 2017 ERA (Ecometrix and Golder, 2018), but the POI concentrations modelled during the 2016 to 2020 period did not exceed the U.S. EPA IRIS Lifetime Risk (1 in 1 million) level of 2.0E-04 $\mu g/m^3$ for continuous lifetime exposure (i.e., residential areas). This value was used for screening because hydrazine does not have published limits.

The selected screening value for nitrogen oxides is 113 $\mu g/m^3$ (CCME CAAQS) for an averaging period of 1 hour. Modelled POI concentrations using ½ hour or 24-hour averaging times were adjusted to 1 hour for comparison to the CCME CAAQS. The adjusted 1-hour POI nitrogen oxide concentration exceeded the CAAQS in 2015, 2018, 2019 and 2020, at a maximum concentration of 157 $\mu g/m^3$. Based on these results, nitrogen oxides were carried forward as a chemical COPC in air for assessment of human health.

3.1.2.2 Chemical COPCs in Surface Water

The surface water screening is based on measurements of COPCs discharged from 2016 to 2020 into the CCW discharge channel, as well as lake water measurements collected in 2014 and 2015. If a COPC was identified in effluent, lake water, or stormwater, it was carried forward for further consideration in the HHRA.

3.1.2.2.1 Liquid Effluent

Clauses 0.2.2 and 7.2.5.2 of CSA N288.6 discuss screening of liquid effluents, highlighting the relationship of effluent monitoring programs to environmental risk assessment and the screening process. Information from 2016 to 2020 on the concentration of COPCs discharged in liquid effluents into the environment was available from PN ECA reports and MISA reports. This information was assessed to aid in COPC selection.

3.1.2.2.1.1 Parameters Monitored Under ECA Requirements

As shown in Figure 2.5, all effluent except for sewage and stormwater is released into the outfall. As such, the final station discharge released from the CCW discharge duct was assessed as the compliance point.

As part of the ECA requirements, the effluent is sampled and analyzed for unionized ammonia, hydrazine, morpholine, pH, and total residual chlorine (TRC). For each of these parameters, the maximum concentration in the effluent from 2016 to 2020 was screened against the Health Canada Guidelines for Canadian Drinking Water Quality (GCDWQ) as per the screening hierarchy for surface water shown on Figure 3.2.

Hydrazine does not have a drinking water quality guideline. However, the U.S. Environmental Protection Agency (U.S. EPA) estimated that a hydrazine concentration of 0.01 µg/L would result in a cancer risk level of 1E-06 (US EPA, 1988), based on a drinking water intake rate of 2 L/day and no amortization. This calculated concentration is used as a screening level for hydrazine in water. As shown in Table A.2 in Appendix A, the maximum concentration for hydrazine (25 µg/L) has exceeded the screening level (0.01 µg/L); therefore, hydrazine has been carried forward for further quantitative assessment in the HHRA.

Morpholine does not have a drinking water guideline and has not been assessed through the US EPA IRIS program. Morpholine alone does not appear to pose a health concern and is used as a solvent and emulsifier in the preparation of wax coatings for fruits and vegetables. Health Canada considered the potential for morpholine to be chemically modified to form N-nitrosomorpholine (NMOR), which is a genotoxic carcinogen in rats, and determined an acceptable daily intake of 0.48 mg/kg bw/day (HC, 2002). Based on a body weight of 70 kg, drinking water ingestion rate of 2 L/day, and hazard quotient of 0.1, a value of 1.7 mg/L was selected as a screening value. The maximum morpholine concentration over the 2016 to 2020 period (0.135 mg/L) is below the identified screening value and therefore morpholine is not carried forward for further quantitative assessment.

Unionized ammonia, pH and TRC are listed in Table A.2, however Health Canada has indicated the guidelines as 'none required' for human health protection. For unionized ammonia, a guideline value is not necessary as ammonia is produced in the body and efficiently metabolized in healthy people; and there are no adverse effects at levels found in drinking water (HC, 2023). Likewise, a pH range of 7.0-10.5 is specified in the GCDWQ to maximize water treatment effectiveness but there is no evidence of an association between the pH of the diet (food or drinking water) and direct adverse health effects (HC, 2023). Health Canada also stated that a guideline value is not necessary for chlorine due to low toxicity at concentrations found in drinking water. The maximum TRC concentration over the 2016-2020 period was 0.024 mg/L, which is lower than the range of free chlorine concentrations in most Canadian drinking water distribution systems of 0.04 to 2.0 mg/L (HC, 2023).

3.1.2.2.1.2 Parameters Monitored Under the MISA Program

Effluent monitoring is required under the MISA program, as described in Section 2.2.2.1.6. As part of the MISA program, COPCs for monitoring are identified for the RLWMS effluent NWTP neutralization sumps, and the combined effluent of PN U1-4 and U5-8 (Table 2.5). Many of the COPCs monitored in the RLWMS and NWTP are not monitored again in the outfall.

For MISA monitoring parameters measured in the RLWMS and NWTP (phosphorus, TSS, zinc, iron, oil and grease, and aluminum), Golder conducted mixing calculations to obtain expected concentrations of COPCs in the CCW based on effluent discharge to the CCW from the RLWMS and the NWTP (Golder, 2007a). Mixing calculations were based on a worst-case scenario, assuming effluent was discharged at the MISA limits. This is conservative since exceedances of MISA limits have not been observed for the majority of the COPCs over the past 19 years (2001-2020). Mixing calculations have been updated based on a CCW flow rate for PN U5-8 of 116 m^3/s (Golder, 2007a) and assumes two CCW pumps per unit operating.

Since none of the MISA monitoring parameters (except for pH) for the RLWMS are measured in the CCW duct after mixing, mixing calculations for the RLWMS discharge to the CCW duct were calculated based on the maximum concentrations of the RLWMS discharge allowed under MISA. The calculated CCW concentrations were compared against the PWQOs and were found to be well below these limits. The concentration in the CCW was calculated according to the following equation:

$$\text{Conc in CCW} = \frac{\text{Conc. In RLWMS effluent} * \text{Effluent flow rate} + \text{Intake Conc.} * \text{CCW flow rate}}{\text{CCW flow rate}}$$

The maximum RLWMS discharge flow rate was assumed to be 0.0126 m^3/s and the CCW flow rate was assumed to be 116 m^3/s (Golder, 2007a).

For the NWTP discharge to the CCW, the concentration in the CCW was calculated according to the following equation:

$$\text{Conc. In CCW} = \frac{\text{Conc. In NWTP effluent} * \text{Effluent flow rate} + \text{Intake Conc.} * \text{CCW flow rate}}{\text{CCW flow rate}}$$

The maximum NWTP discharge flow rate was assumed to be 0.02 m^3/s and the CCW flow rate was assumed to be 116 m^3/s (Golder, 2007a). The calculated CCW concentrations were compared against the PWQOs and were found to be well below these limits.

During the 2016-2020 period, two MISA non-compliance events were reported in 2018 for oil and grease. During these events which took place on July 31 and October 31, Active Liquid Waste Tank 4 was discharged via the CCW system to Lake Ontario at concentrations of 59 mg/L and 52 mg/L, respectively. These concentrations are above the MISA daily limit of 36 mg/L at the RLWMS (Table 2.5). However, based on the dilution provided by CCW flows the non-compliance events result in only a negligible increase in the concentration at the CCW discharge point.

Therefore, based on mixing calculations, no PWQO exceedances in the CCW are expected for the MISA parameters, as shown in Table 3.1.

Table 3.1: Summary of CCW Mixing Calculations for RLWMS and NWTP

Parameter	Units	Intake Concentration[1]	MISA Limit at Effluent Discharge	Maximum Concentration in CCW	PWQO
RLWMS A, B					
Phosphorus	mg/L	<0.01	1	<0.01	0.02
Total suspended solids	mg/L	<2	73	<2	N/A
Zinc	mg/L	0.01	1	0.010	0.03
Iron	mg/L	0.025	9	0.026	0.3
Oil and Grease	mg/L	<1	36	<1	Narrative
NWTP					
Aluminum	mg/L	0.004	13	0.0056	0.075
Total suspended solids	mg/L	<2	70	<2	N/A
Iron	mg/L	0.0025	2.5	0.0253	0.3

Note:
[1] (Golder, 2007a)

3.1.2.2.2 Lake Water Sampling

As part of the updated baseline environmental program, lake water data in the vicinity of the PN site were collected in 2014 and 2015 to quantify the concentration of COPCs in the PN outfalls. The lake water results are summarized in Appendix A, Table A.2.

In 2014, an EMP supplementary study for hydrazine in surface water was conducted (Ecometrix, 2015). The objective was to obtain hydrazine surface water results at a low detection limit of 0.05 µg/L. In previous studies, the detection limit for hydrazine in lake water samples was 5 µg/L, higher than levels corresponding to 1E-05 and 1E-06 cancer risk. In 2014, samples were collected in July, August, and September at the PN outfalls at three locations each (i.e., ~100 m, 250 m and 500 m from discharge). Additional samples were collected at locations 500 m and 1000 m east and west of the discharge at a location 200 m from shore, as shown in Figure 3.4.

In 2015, water quality samples were collected from five locations (see Table 3.2 and Figure 3.3) in the vicinity of the PN outfalls, and one control location near Cobourg WSP. Samples were analyzed for alkalinity, ammonia (total and un-ionized), biochemical oxygen demand (BOD), chemical oxygen demand (COD), hardness, pH, conductivity, temperature, total suspended solids (TSS), total residual chlorine (in-situ), petroleum hydrocarbons (PHC F1 to F4), morpholine, metals, and radionuclides.

Table 3.2: Lake Surface Water 2015 Sampling Locations and Descriptions

Location	Sample ID	UTM Easting and Northing	Description	Sample Depth (m)	Depth to Bottom (m)
PN outfalls	LW-10	655083 E 4852644 N	PN U1-4 outfall (mid channel)	mid-depth sample – 2 m	2.7 to 3.1
	LW-21	655993 E 4852410 N	PN U5-8 outfall (mid channel)	mid-depth sample – 2 m	4.2 to 4.5
PN intake	LW-9	655200 E 4852011 N	south of opening to intake channel (in front of fish diversion net)	0.3 m and 5 m	5.4 to 5.5
Frenchman's Bay mouth	FB-1	653983 E 4852540 N	at a location of 5 m depth at the mouth	0.3 m and 5 m	5.5 to 5.7
PN East Side	LWE-1	656580 E 4852203 N	at a location of 5 m depth, offshore of stormwater location M5-1	0.3 m and 5 m	5.3 to 5.7
Lake Ontario Control	LWC-1	727080 E 4869401 N	east of PNGS near Cobourg Water Supply Plant	0.3 m and 5 m	16.1 to 16.5

Maximum measured concentrations from the 2014 hydrazine and 2015 lake water sampling programs were compared to selected health-based screening criteria following the hierarchy presented on Figure 3.2 and listed below:

- The more conservative of the Health Canada Guidelines for Canadian Drinking Water Quality (GCDWQ) (HC, 2023); or the MECP GW1 drinking water component value, which is based primarily on the Ontario Drinking Water Quality Standard (ODWQS) as listed in O. Reg. 169/03. The ODWQS was generally adopted the GCDWQ, except for recent updates to some of the GCDWQs. For contaminants without an ODWQS, the MECP supplemented with values from other jurisdictions, as described in (MECP, 2011). Some of the GCDWQ values have recently been updated by Health Canada in 2019 and 2020 but not in the ODWQS, and values have increased (e.g. barium, cadmium, copper, lead, and manganese). However, the ODWQS remains legally enforceable under O. Reg. 169/03 and therefore the higher GCDWQ values were not used for screening.

- Modified toxicity or screening values available from other sources: Guidelines available from other jurisdictions (e.g. British Columbia Ministry of Environment (BC MOE) Source Drinking Water Quality Guidelines; US EPA Regional Screening Levels (RSLs) for resident tap water – target hazard quotients of 0.2); toxicity values from US EPA Integrated Risk Information System (IRIS) or Health Canada (HC)).

- Mean background concentrations (based on concentrations measured at LWC-1 in 2015). The screening value was set to the mean background concentration if there are no federal and provincial drinking water quality guidelines.

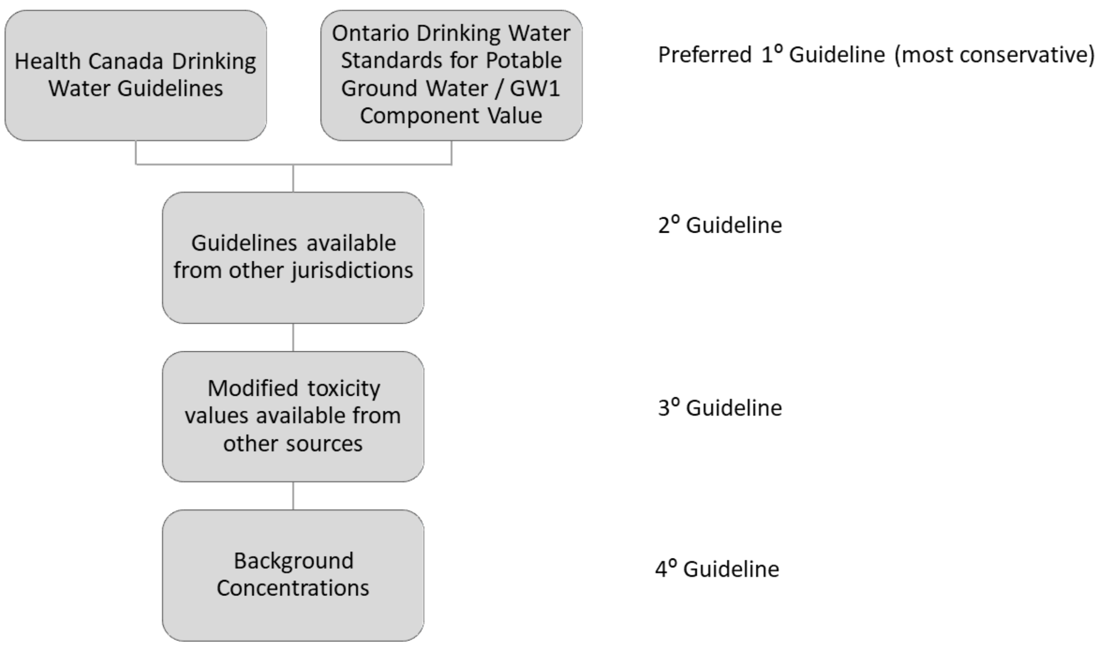


Figure 3.2: Screening Hierarchy for Chemical COPCs in Surface Water for the HHRA

Based on the lake water screening presented in Appendix A (Table A.2), hydrazine is carried forward for further quantitative assessment in the HHRA.

Figure 3.3: 2015 Lake Water Sample Collection Locations

Figure 3.4: Locations of the 2014 Hydrazine Sample Collections near the PN Site (22 July, 15 August and 10 September)

3.1.2.2.3 Stormwater

Stormwater runoff from the PN site is collected by the stormwater drainage system and directed through drainage pathways south to Lake Ontario. Surface drainage around the PN site is comprised of 19 catchments, as shown on Figure 3.5. A brief discussion of the drainage pattern is presented below (Golder, 2007a):

- Catchments 1 and 2 discharge to PN U1-4 discharge channel;
- Runoff from Catchment 3 is collected by catch basins, directed to a subsurface yard drainage network and discharged directly to Lake Ontario via a submerged outfall;
- Runoff from Catchments 4 and 5 is collected by catch basins, directed to a subsurface yard drainage network and discharged to the intake channel via submerged outfalls;
- Runoff from Catchment 7 is collected by a system of catch basins and subsurface drains and discharged to PN U5-8 discharge channel;
- Runoff from Catchment 8 is directed through culverts and ditches and discharged to PN U5-8 discharge channel;
- Catchments 6 and 9 each drain through a pipe into PN U5-8 discharge channel; and
- Catchments 10 through 16A drain directly to the Lake Ontario shoreline. These specific catchment areas are expected to be different with recent developments in the area and the estimated current catchments are shown in yellow on Figure 3.5. Water in this area however, continues to discharge to the Lake Ontario shoreline. The discharge points are approximately 6 m to 10 m above the Lake Ontario water level.

The 2017 ERA (EcoMetrix, 2014) discussed the results of several stormwater sampling campaigns conducted between 1990 and 2006. Overall, the conclusions from the 1997, 2002, and 2006 studies indicate that stormwater quality has not resulted in any unexpected or adverse effects on the environment. The 2017 ERA (Ecometrix and Golder, 2018) included results from the updated baseline stormwater sampling campaign that was completed in 2015/2016 to characterize the current quality of stormwater runoff from PN (see Table 1.2).

The 2015/2016 stormwater sampling campaign did not include monitoring of Catchments 7, 9, 11, 12, 14, 15, and 16/16A. Catchments 7 and 9 discharge into the PN U5-8 discharge channel where flows are diluted with other effluent streams. Lake water concentrations at the PN U5-8 discharge channel were sampled in 2015 (Location LW-21) providing a more direct measurement of the cumulative inputs to the water quality at PN U5-8 discharge channel (see Section 3.1.2.2.2). Catchments 11, 12, 14, 15 and 16/16A are part of the East Complex where changes to stormwater catchments will likely take place after completion of the PWMF Phase II expansion. Once the expansion has been complete, these locations will be sampled to assess changes in stormwater catchments to satisfy recommendations resulting from the 2017 ERA (Ecometrix and Golder, 2018; OPG, 2017b).

Based on the foregoing, the most recent data available for the characterization of stormwater runoff continues to be represented by the 2015/2016 baseline sampling campaign and are further discussed in this section.

The screening of stormwater quality against water quality guidelines is presented in Appendix A). The stormwater quality screening focused on stormwater released to the PN outfalls (Catchments 1 and 2 to PN U1-4; Catchments 6 and 9 to the PN U5-8), and stormwater discharged directly to Lake Ontario (Catchment 3 to the west of the intake channel; Catchments 10 and 13 to the east of the intake channel). Concentrations in stormwater discharged into the intake channel (Catchments 4 and 5) were not included in the assessment as that stormwater is redirected into the station. However, for completeness, stormwater data from Catchments 4 and 5 are presented in Appendix F. There was one toxicity test failure; however, this water is redirected into the station; therefore, it was not considered to be of concern.

During the 2015/2016 stormwater sampling campaign, a flow monitor was installed in M2-1 only. The flow at all other locations, with the exception of M5-1, was calculated based on historical rainfall vs flow measurements. The rainfall depth (mm) was multiplied by a volume to depth ratio based on previous sampling events to provide the rainfall volume (m^3) at each location. This volume was divided by the duration of the storm event to provide the flow (m^3/s). This use of historical data was considered valid as these catchment areas had not changed.

The catchment area of M5-1 has however changed with the construction of the PWMF II and other modifications. Based on this change the flow resulting from various rainfall depths was calculated via the Environmental Protection Agency Storm Water Management Model 5.0 (SWMM5) hydrologic model, and verified by the measurements at M2-1. A discussion of this model and verification was provided in Appendix G. For M5-1, the modelled runoff volumes provided in Table G.3 were divided by the duration for each storm event to obtain the flows.

PN Discharge Channels

Stormwater sampling results from the 2015/2016 sampling campaign from each relevant catchment were compiled to determine the maximum concentration potentially released to the PN discharge channels. Dilution calculations were performed to determine the concentration in the discharge channel for each of the monitored parameters. The maximum stormwater runoff to PN U1-4 and U5-8 discharge channels is 1.13 and 3.74 m^3/s, respectively. This runoff, from June 2016, is significantly higher compared to previous data (Golder, 2007a) and the other three quarters measured in 2015. The stormwater runoff flow used for each discharge channel was the maximum flow of four monitoring events from the applicable catchments. The flowrate used in the calculations for the PN U1-4 discharge channel is 48 m^3/s. The flowrate used for the PN U5-8 discharge channel is 116 m^3/s (Golder, 2007a), which assumes two CCW pumps per unit operating.

Runoff to Lake Ontario

Stormwater sampling results from the 2015/2016 study from Catchments 10-16A located east of the station and data from Catchment 3 located west of the station were assessed separately. The flow in the wave zone in Lake Ontario was determined based on the assumption that the wave zone extends out to 150 m east of the station and 120 m west of the station and is well mixed over a depth of 2 m (based on the Canadian Hydrographic Service nautical map of the area). The current speed was taken as the average of the easterly and westerly current speeds from the 2011-2015 period (0.197 m/s). Therefore, lake flow to the east and west of the station is 29.5 m^3/s and 23.6 m^3/s, respectively.

Dilution calculations were performed to determine the concentrations of COPCs in the wave zone at the shoreline of Lake Ontario. Stormwater runoff flowrate was calculated or measured (for M2-1) for each of the four stormwater events monitored in 2015/2016 – based on the estimated runoff volume and event duration. The maximum loading rate was determined from monitoring data and stormwater runoff. The maximum concentration in the lake was then estimated from the maximum loading rate and lake flow along the shoreline.

Overall Conclusion

The final concentration in each of the discharge channels, and in the lake, resulting from stormwater runoff was compared to water quality guidelines according to the hierarchy presented in Figure 3.2. The screening tables are presented in Appendix A (Tables A.4a to Table A.4d) and there were no exceedances of the selected benchmarks. The results of the screening assessment are in agreement with the conclusions of the previous stormwater monitoring programs.

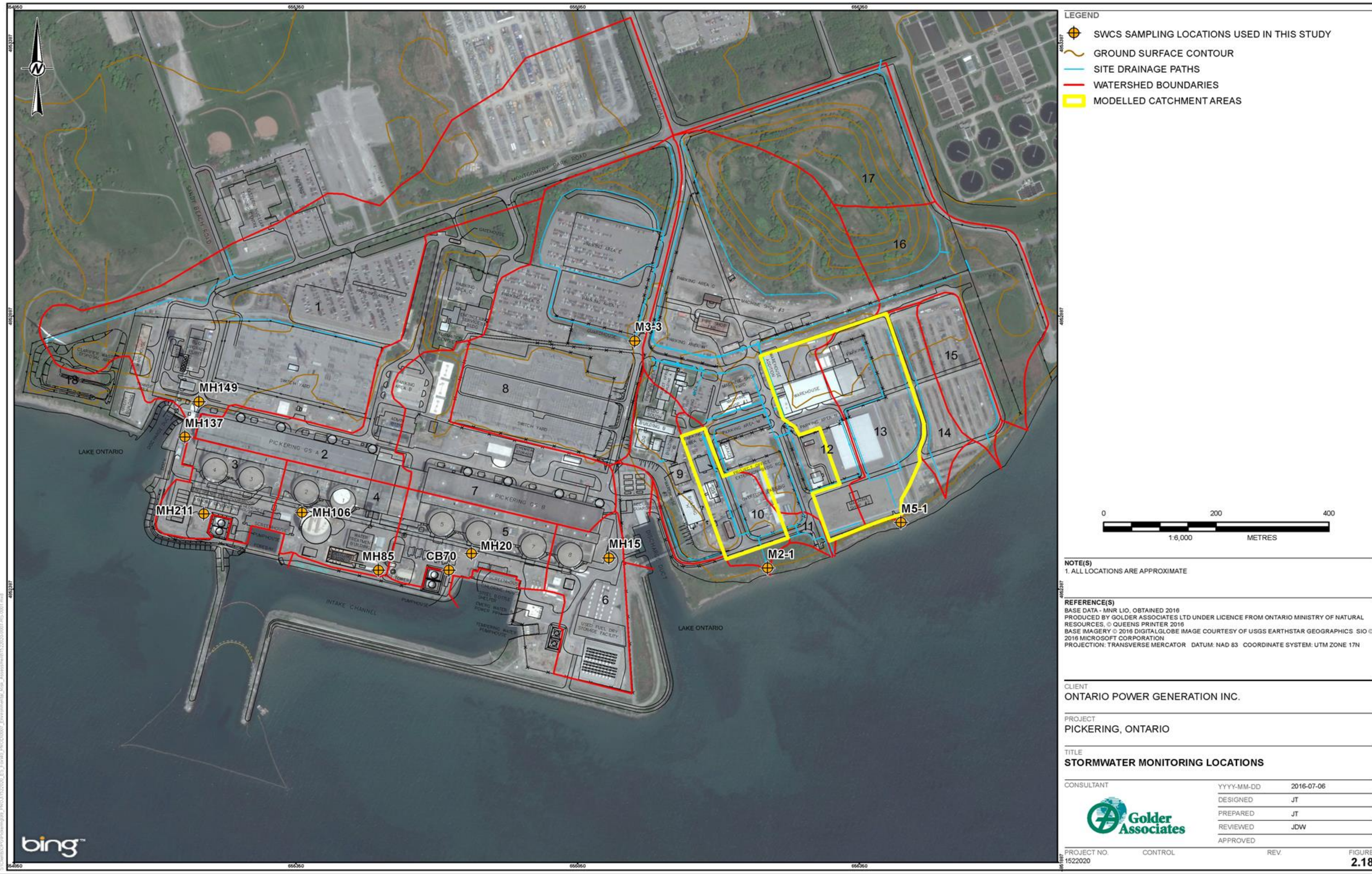


Figure 3.5: Catchment Areas for Pickering Nuclear and Stormwater Sampling Locations

3.1.2.3 Chemical COPCs in Soil

For the HHRA, potential risks from soil were determined to be of little concern. On-site workers, contractors, and visitors are potentially exposed to on-site soil; however, these exposures are considered and controlled through the Health and Safety Management System Program, and are outside of the scope of the HHRA, as discussed in Section 3.1.1.1.1. Human exposure to COPCs from off-site soil is unlikely, since the results of the air screening presented in Section 3.1.2.1 show acceptable concentrations for air contaminants that could deposit on soil. The PN site is not a source of dust. The PN site is fully developed and does not contain unpaved roads. Any releases from PN and subsequent off-site deposition of non-radiological particulates (metals) will be lost against the background soil levels.

An EcoRA screening for non-radiological COPCs in soil is presented in Section 4.1.3.3.

3.1.2.4 Chemical COPCs in Groundwater

A number of hydrogeological investigations have been completed at the PN site primarily related to elevated tritium levels in groundwater (see Section 3.1.2.7), but with some investigations related to other COPCs such as petroleum hydrocarbons, chloride, and metals in specific potential source areas.

Since December 31, 2020, the PN site has had 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" (Ecometrix, 2020b). The GWPP is a comprehensive document that defines groundwater protection goals for the PN site based on site-specific hydrogeological conditions and groundwater end uses that are presented in a groundwater conceptual site model (CSM) (Ecometrix, 2020a). A systematic planning process is used to design a groundwater monitoring program (GWMP) that collects the information required to meet each of the GWPP objectives. Groundwater monitoring and reporting, beginning in 2021, follows the design provided in the GWMP. Prior to 2021, groundwater monitoring had been ongoing for many years (decades) at the PN Site, most recently under the Groundwater Monitoring Program Design (Ecometrix, 2012). Groundwater quality results from groundwater monitoring conducted from 2013 to 2020 (OPG, 2014b, 2015, 2016c, 2017c, 2018e, 2019b, 2020e, 2021e) are consistent with the previous assessment.

In the groundwater CSM, structures, systems, and components (SSCs) were identified in order to identify high priority SSCs: those which act as potential sources of chemicals to groundwater. Chemicals associated with the SSCs were screened as COPCS for monitoring in the GWMP on the basis of recent (primarily, 2012-2018) groundwater concentrations of those chemicals at the PN Site. Tritium was identified as a COPC in groundwater at the PN Site and is discussed further in Section 3.1.2.7. There are no published standards for tritium in groundwater; tritium was included as a COPC because of its presence in groundwater in association with SSCs.

Non-radiological COPCs in groundwater at the PN Site monitored during the 2016-2020 period ((OPG, 2017c, 2018e, 2019b, 2020e, 2021e)) focused on PHCs F1-F4), benzene, toluene, ethylbenzene, and xylenes (BTEX) compounds, and volatile organic compounds (VOCs, only in 2017 and 2019). Based on the screening assessment of past measurements, non-radiological COPCs in groundwater at the PN Site include dissolved iron, BTEX compounds, and PHCs. Screening benchmarks for non-radiological COPCs included:

- Ontario Ministry of the Environment, now MECP, Table 3 (Full Depth Generic Site Condition Standards in a Non-Potable Ground Water Condition) or Table 9 (Generic Site Condition Standards for Use within 30 m of a Water Body in a Non-Potable Ground Water Condition).
- For substances without MECP Table standards, data were compared against screening levels based on 10 times (10x) the lowest of the Ontario Provincial Water Quality Objectives (PWQO) and the CCME water quality guidelines. The 10x factor is consistent with the MECP (MECP, 2011) derivation of the groundwater to surface water pathway component values (GW3), which assumes at least 10-fold dilution of groundwater in surface water.

Monitoring of BTEX and PHCs occurs in association with the standby generators (U1-4 SG and overflow tank area and U5-8 SG), the emergency power generators, and the Emergency Mitigating Equipment Diesel Generators. PHCs are monitored proactively around the emergency power generators because of the presence of underground fuel oil piping. However, historical and recent data for PHC compounds have always been non-detect. Likewise, PHCs will be monitored (2021-forward) proactively around the Fukushima diesel generators, and dissolved iron – which, when present at elevated concentrations, can be an indicator of hydrocarbon degradation – is being monitored in a shoreline well downgradient of the generators.

PHCs are present in groundwater in association with the U1-4 SG and overflow tank area and U5-8 SG. In all three areas, monitored natural attenuation programs to monitor petroleum hydrocarbon impacts have been ongoing since 2011 (PGL, 2011). The PHC plumes are, overall, considered to be stable (PGL, 2018). Plume fringe wells were identified in the GWMP, and for all three areas, BTEX and PHC are below detection in the plume fringe wells located closest to surface water bodies (PGL, 2018). Thus, the data collected to date do not support migration of PHCs in groundwater from these areas to the intake channel or Lake Ontario. In addition, recreational residents are not allowed to swim in the intake channel, and other recreational use would occur within Lake Ontario. The groundwater flux to Lake Ontario to the south of the PN site is likely to be small – based on the estimated groundwater velocity and (groundwater-withdrawing) influence of site infrastructure (CH2M Gore and Storrie, 2000). Concentrations of COPCs in groundwater would thus be subject to considerable dilution before they can migrate with surface water to a point of water intake for human consumption. The nearest water intake at Ajax is approximately 7 km east of the Pickering Nuclear site and is not at any risk due to PHCs in groundwater on the site.

As noted above, dissolved iron in groundwater can be an indicator of microbial degradation of PHC compounds in groundwater. However, it can be elevated for other reasons, and background concentrations of dissolved iron vary naturally by HU at the PN Site (Ecometrix, 2020a). Dissolved iron has been (and continues to be in the GWMP) monitored downgradient of the East and West Landfills and in the shoreline wells. Dissolved iron concentrations exceeding the groundwater screening benchmark (3 mg/L) have been measured in three monitoring wells along the Lake Ontario shoreline. No unacceptable risk to human receptors from iron in groundwater is predicted, for the following reasons:

- Dilution of groundwater from beneath the PN site in Lake Ontario and the long transport pathway to the nearest water intake for human consumption (as explained above);
- Oxidation of dissolved iron (overwhelmingly ferrous iron when present at elevated concentrations in groundwater) and precipitation of the iron as an iron oxide mineral will occur very rapidly upon exposure to oxygenated waters of Lake Ontario; and
- The screening benchmark applied in the CSM (3 mg/L iron) is based on risks to freshwater aquatic life. Health Canada has not set a maximum acceptable concentration for iron in drinking water (HC, 1978). Iron is an essential element with no evidence for toxic effects unless large quantities of iron are ingested.

There are no groundwater supply wells downgradient of potential source areas on-site. As water on the PN site is not used for human consumption, the only on-site pathway for human exposure to groundwater would be from ingestion of water from Lake Ontario after dilution of the groundwater in the Lake. Concentrations of potential chemical stressors in off-site drinking water wells are not influenced by PN.

Therefore, although COPCs (BTEX and PHCs, dissolved iron) have been identified in groundwater as part of the N288.7-compliant GWPP at the PN site, the concentrations for groundwater that can migrate to Lake Ontario are below screening benchmarks. The groundwater pathway is not carried forward for further inclusion in the HHRA.

3.1.2.5 Radiological COPCs in Air and Water

Selected radiological stressors are considered of public interest and therefore are carried forward quantitatively in the HHRA and do not undergo a formal screening assessment. The relevant radionuclides that are the focus of the quantitative assessment are described below.

Airborne and waterborne radioactive emissions from the years 2016 to 2020 were analyzed and compared against radioactive emissions reported in the 2017 Pickering ERA (Ecometrix and Golder, 2018). Emissions from the five year period 2016 to 2020 (see Table 3.3 and Figure 3.6) are within the range of historical emissions reported in the 2017 Pickering ERA (Ecometrix and Golder, 2018), except gross beta-gamma waterborne emissions which increased in 2020. Average radiological emissions over the 2016 to 2020 period ranged between <0.01 to 5.62% of Derived Release Limits (DRL), as shown in Table 3.3.

Airborne Emissions

The average PN tritium oxide airborne emissions from 2016 to 2020 have increased slightly compared to average emissions from the previous 2011-2015 period (Table 3.3). In 2016, the increase was primarily attributed to the presence of tritiated water in a Fuel Transfer Conveyor Tunnel, and the resulting airborne tritium oxide emissions being vented to a monitored stack (OPG, 2017f). Mitigating actions were taken to reduce tritium oxide airborne emissions from this source. In 2017, the slight increase was primarily attributed to dryer performance issues and a rupture disk failure on Unit 1, which has since been corrected (OPG, 2018h). Further improvements in airborne tritium management were made in 2018 and 2019. In 2020, tritium oxide emissions increased due to a heat transport system leak on Unit 1 and a moderator purification valve leak on Unit 6. Corrective actions were taken to repair the leaks and the tritium oxide emissions have since returned to lower levels.

The average noble gas and iodine emissions from 2016 to 2020 have decreased or are identical compared to average emissions from the previous 2011-2015 period (Table 3.3). Typically, their emissions are below the detection limit and their contribution to the overall public dose is minimal. In 2017, a significant increase in particulate airborne emissions was recorded at PN U5-8 in week 7 of the second quarter and week 1 of the third quarter, both related to maintenance performed on the Service Wing lab duct (OPG, 2017g, 2017h). In both cases, emissions returned to normal levels the following week.

The average PN carbon-14 airborne emissions from 2016 to 2020 have increased slightly compared to average emissions over the 2011-2015 period (Table 3.3). The highest annual emission rate observed in 2018 was due to work associated with the moderator purification system on Units 1 and 6 (OPG, 2019e).

Waterborne Emissions

The average tritium oxide waterborne emissions from 2016 to 2020 was generally stable to slightly higher compared to average emissions from the 2011-2015 period (Table 3.3). A slight increase was observed in 2017, which was attributed to a leak in the Unit 5 moderator pit. Tritiated water from the moderator room was processed and discharged through the active liquid waste system. Sealing and repair work to the moderator pit was completed in April 2017. Slightly elevated tritium oxide emissions from 2018 to 2020 are attributed to increased processing of active liquid waste.

The average gross beta-gamma waterborne emissions remain low but have increased compared to average emissions from the 2011-2015 period (Table 3.3). The increases seen in 2016 and 2020 were primarily attributed to spontaneous release of concentrated, entrained active lake sediment materials from the Reactor Building Service Water system, and not a station generated source of activity (OPG, 2017f, 2021c). An increase seen in 2019 was the result of an increase in electrical production at PN (23.6 TWh in 2019) compared to that in 2017 and 2018 (21.4 and 20.8 TWh, respectively) (OPG, 2020f).

The average carbon-14 waterborne emissions from 2016 to 2020 remain low and have decreased slightly compared to average emissions from the 2011-2015 period (Table 3.3). Their contribution to the overall public dose is minimal.

Table 3.3: Radioactive Emissions from PN

Media	Parameter	Average (2017 ERA)[1]	Year					Average (2016-2020)	% of DRL[2]
			2016	2017	2018	2019	2020		
Air	Tritium Oxide (Bq/a)	5.16E+14	6.80E+14	6.90E+14	6.20E+14	5.60E+14	6.50E+14	6.40E+14	0.63
	Noble Gas (γBq-MeV/a)	1.32E+14	1.16E+14	1.54E+14	1.25E+14	1.30E+14	4.50E+13	1.14E+14	0.43
	I-131 (Bq/a)	1.76E+07	1.40E+07	1.39E+07	1.17E+07	1.40E+07	1.00E+07	1.27E+07	<0.01
	Particulate (Bq/a)	1.15E+07	2.95E+07	2.07E+08	7.70E+06	5.70E+06	5.80E+06	5.11E+07	0.01
	Carbon-14 (Bq/a)	1.84E+12	2.40E+12	2.60E+12	3.70E+12	2.60E+12	2.30E+12	2.72E+12	0.10
Water	Tritium Oxide (Bq/a)	3.24E+14	3.20E+14	3.80E+14	4.20E+14	4.30E+14	4.30E+14	3.96E+14	0.05
	Gross Beta-Gamma (Bq/a)	2.72E+10	5.78E+10	2.65E+10	4.33E+10	7.80E+10	3.20E+11	1.05E+11	5.62
	Carbon-14 (Bq/a)	3.84E+09	4.70E+09	1.90E+09	1.10E+09	3.50E+09	1.80E+09	2.60E+09	<0.01

Notes:

1. Average from the 2017 ERA (Ecometrix and Golder, 2018) is the average of emissions from 2011-2015.
2. The DRL used for comparison to 2016-2020 average emissions is obtained from PN DRL 2016 report (OPG, 2017i).

Figure 3.6: Summary of PN Emissions Data from 2016-2020

The Radiation and Radioactivity TSD (SENES, 2007d) identified a number of radionuclides released to air and water that should be carried forward for the dose assessment. The 2016 DRL Report for PN presents the same effluent release groups for air and water, with the exception of including gross alpha for both air and water (OPG, 2017i).

The DRLs for the effluent release groups were calculated based on the selection of the radionuclide with the most restrictive DRL, according to the process outlined in the COG DRL Guidance document. Radionuclides were selected based on the following criteria for inclusion:

- Radionuclides are regularly present in the effluent; and
- Radionuclides represent no less than 1% of the total radioactivity present (exclusive of naturally occurring radionuclides such as beryllium-7, potassium-40, radon and radon daughters).

Based on these criteria, the radionuclides selected for use in DRL calculations as show in Table 3.4 were considered appropriate for carrying forward in the risk assessment.

The limiting radionuclides (i.e., the radionuclide with the most restrictive DRL) for particulates in air and for gross beta-gamma in water were used to represent all radionuclides in each grouping. The 2016 DRLs (OPG, 2017i) indicate that cobalt-60 is the limiting radionuclide for particulates in air, and cesium-134 is the limiting gross beta-gamma radionuclide in water.

Table 3.4: Radionuclides Considered for Derivation of DRLs

Category	Radiological COPC
Air	tritium, noble gases, carbon-14, I (mixed fission products), particulates (gross beta-gamma): ^{32}P, ^{35}S, ^{46}Sc, ^{51}Cr, ^{54}Mn, ^{59}Fe, ^{60}Co, ^{65}Zn,^{89}Sr, ^{90}Sr (^{90}Y), ^{95}Zr, ^{95}Nb, ^{106}Ru, ^{124}Sb, ^{125}Sb, ^{131}I, ^{134}Cs, ^{137}Cs, ^{144}Ce, ^{153}Gd, ^{160}Tb, ^{203}Hg, ^{234}Th
Surface water	tritium, carbon-14, gross beta-gamma: ^{32}P, ^{35}S, ^{46}Sc, ^{51}Cr, ^{54}Mn, ^{59}Fe, ^{58}Co, ^{60}Co, ^{90}Sr (^{90}Y), ^{95}Zr, ^{95}Nb, ^{99}Mo, ^{103}Ru, ^{106}Ru, ^{113}Sn, ^{122}Sb, ^{124}Sb, ^{125}Sb, ^{131}I, ^{134}Cs, ^{137}Cs, ^{152}Eu, ^{154}Eu, ^{153}Gd, ^{159}Gd, ^{160}Tb, ^{181}Hf, ^{203}Hg

Source: (OPG, 2017i)

Gross alpha radionuclides do not need to be carried forward for the risk assessment. The level of airborne and waterborne gross alpha emissions from OPG nuclear facilities has been considered to be negligible (OPG, 2005b). This position is supported by determination of alpha activity in the heat transport water and estimates of the maximum probable emission levels under normal and abnormal operating conditions. The airborne exhaust systems at PN contain HEPA filters which continuously filter particulate from the airborne effluents, thus capturing the alpha emitting particles, resulting in negligible emissions. A study on monthly gross alpha waterborne emissions was performed to establish an appropriate monitoring methodology (OPG, 2006). Based on 2015 monitoring data, gross alpha waterborne concentrations at PN RLWMS are at

Method Detection Limit (MDL) and their emissions are at a very small fraction (0.00002%) of the monthly DRL. Based on 2015 monitoring data, gross alpha airborne emissions are approximately 0.0005% of the weekly DRL.

3.1.2.5.1 Pickering Waste Management Facility

As discussed in Section 2.2.1, the PWMF is comprised of the PWMF Phase I site and PWMF Phase II site. Dose rate calculations were performed as part of the PWMF Safety Analysis Report (OPG, 2018a).

Table 3.5 summarizes the expected conservative dose rates based on the PN property boundary locations near the facilities, when the facilities are at full capacity and at existing baseline capacity. The fields outside the DSC storage buildings are due primarily to contributions from direct gamma radiation and secondarily from gamma skyshine. The neutron dose rate represents a minor contribution (approximately 4%) of the expected gamma dose rate (OPG, 2022). The neutron dose rate is negligible compared to gamma dose rates.

In 2017, air kerma rates from the PWMF were measured at various locations over Lake Ontario (OPG, 2018i). At a distance of 400 m from the PWMF, the measured air kerma rate was below the detection limit of 0.33 nGy/h. At a distance of 1 km from the PWMF, the air kerma rate was estimated to be negligible assuming an inverse square relationship with distance and a further reduction of a factor of 1,000 due to scattering in air. Based on the 2017 assessment, it was determined that air kerma rates from the PWMF are not significant for potential critical groups farther than 1 km from the source – all potential critical groups except for the Sport Fisher (OPG, 2018i).

The annual contribution to the Sport Fisher dose from the PWMF is estimated in the exposure assessment for the HHRA.

Table 3.5: Expected Dose Rates at Boundary Locations from PWMF Phase I and Phase II Sites

Site	Location	Dose Rate (μSv/h) at Full Capacity (OPG, 2018a)
PWMF Phase I	Station site boundary, 850 m east of the building wall	1.04E-03
	Eastern lakeside exclusion zone boundary (420 m from the PWMF Phase I storage areas)	7.23E-04
PWMF Phase II	Pickering NGS east property boundary	1.04E-03
	Lakeside exclusion zone boundary (about 340 m south-east over Lake Ontario at the closest location	7.23E-04

Notes:
Baseline assumes PWMF Phase I at 25% capacity, PWMF Phase II at 48% capacity.

3.1.2.6 Radiological COPCs in Soil

The Radiation and Radioactivity TSD (SENES, 2007d) identified cesium-134, cesium-137, cobalt-60, and potassium-40 as relevant COPCs for soil and sediment. However, potassium-40 is environmentally abundant and not associated with station operations. The cesium and cobalt isotopes are included as COPCs in order to address potential concern about deposition of particulate activity. Only cesium-134 and cobalt-60 are specific to reactor operations, and these are typically not detected in EMP monitoring of either soil (in 2017) and sediment (in 2019) around the facility (OPG, 2018h, 2020f). The presence of cesium-137 is primarily due to atmospheric weapons test fallout and not reactor operations. However, exposure to cesium-134, cesium-137, and cobalt-60 in soil are included in the public dose calculations and are therefore carried forward as COPCs.

On-site workers, contractors, and visitors are potentially exposed to on-site soil; however, these exposures are considered and controlled through the Health and Safety Management System Program and Radiation Protection Program, and are outside of the scope of the HHRA, as discussed in Section 3.1.1.1. Human exposure to particulate activity in off-site soil is considered to be of minimal concern because particulate releases are low, and because monitoring of soil around the site perimeter continues to show either non-detects, or in the case of cesium-137, relatively constant levels within the background range.

The primary transport pathway of radiological COPCs to soil on-site and off-site is through deposition from air. However, two COPCs, HT and noble gases, are not expected to partition to soil. In addition, most of the radioiodines have short half-lives and would disappear quickly from soil, with the exception of I-131, which has a half-life of 8.03 days (CNSC, 2017b). The beta-gamma released to air, represented conservatively by Co-60, will deposit to soil, and is considered to be a COPC in soil. In addition, gross beta-gamma released to surface water, represented conservatively by Cs-134, can be transferred to soil by irrigation of gardens, and is considered as a COPC in soil for rural residents with gardens. Cs-137 was formerly the limiting radionuclide in water (replaced by Cs-134 in the 2016 DRL report) and is commonly found in liquid effluent.

The final list of COPCs for soil was therefore as follows: C-14, Co-60, Cs-134, Cs-137, HTO (pore water), and I-131.

3.1.2.7 Radiological COPCs in Groundwater

There is potential for site groundwater to migrate to surface water (Lake Ontario); however, groundwater flux from the site into Lake Ontario is likely to be small based on the estimated groundwater velocity and influence of site infrastructure (CH2M, 2000); therefore, any COPCs in groundwater that reach the lake are subject to considerable dilution before they can migrate with surface water to a point of water intake for human consumption. The nearest water intake at Ajax is approximately 7 km east of the Pickering Nuclear site and is not at any risk due to constituents in groundwater on the site. Measured tritium at the Ajax WSP was used in the public dose calculation, and therefore, any groundwater influence is captured in the assessment. The surface water radionuclide concentrations include the contribution from groundwater, including groundwater captured by station structures (i.e., Turbine Auxiliary Bay foundation drains) and the groundwater discharged directly to Lake Ontario.

A groundwater evaluation criterion for tritium has been developed as part of the N288.7-compliant GWPP for the PN site that would be protective of the drinking water pathway from the Ajax WSP intake. A tritium concentration of 6.19×10^9 Bq/L was derived to be protective of human receptors (Ecometrix, 2020b). Over the past five years of groundwater monitoring, none of the measured groundwater concentrations have exceeded the screening criterion (OPG, 2017c, 2018e, 2019b, 2020e, 2021e).

The on-site groundwater is not considered potable. There are no groundwater supply wells downgradient of potential source areas on-site. Off-site drinking water wells may be influenced by the atmospheric tritium plume and this is taken into account in the public dose calculations as part of the annual EMP.

3.1.2.8 Noise

Noise is the only physical stressor mentioned in CSA N288.6-12 as a potential human stressor, and is the only physical stressor associated with PN that is of potential concern to humans. Physical stressors relevant to ecological receptors are discussed in Section 4.1.3.11.

Noise emissions from PN originate from various on-site noise sources. During the 2016-2020 period, the PN site operated under amended ECA No. 4766-A3YMB9, issued on December 2, 2015. This was replaced in 2019 by amended ECA No. 2372-BESHSC, issued October 17, 2019. The ECA application includes an assessment of on-site noise sources (OPG, 2019a). ECA is an environmental approval issued by the MECP that helps to protect the natural environment from emissions such as air and noise, but is not a human health assessment. According to a 2018 Acoustic Assessment Report, significant noise sources include following types of onsite activities:

- Standby gas turbine generating sets for both PN U1-4 and U5-8;
- Emergency power supply generators;
- Auxiliary Diesel Generators;
- Building exhaust systems;
- Chillers and air conditioning units;
- Combustion turbine units; and
- Emergency fire pumps.

Past noise assessments, including those conducted annually since 2018 at receptor locations within the vicinity of the PN concluded that noise levels were compliant with the appropriate noise level limits (OPG, 2011a, 2019a, 2020a, 2021a).

As part of the updated baseline environmental program, a noise monitoring program was carried out to monitor existing ambient noise levels. The noise monitoring program included collecting existing noise levels for two environmental components: Environmental Noise (human receptors) and Environmental Noise (ecological receptors). Results for the noise monitoring program for ecological receptors is discussed in Section 4.1.3.11.1.

As defined by the MECP noise guideline, "*NPC 300 Environmental Noise Guideline, Stationary and Transportation Sources – Approval and Planning*" (NPC 300) (MOECC, 2013), exclusionary sound level limits are defined for the Daytime, Evening and Night-time periods as follows:

- Daytime – 07:00 to 19:00;
- Evening – 19:00 to 23:00; and
- Night-time – 23:00 to 07:00.

The Environmental Noise (human receptors) locations, also known as Point(s) of Reception (POR(s)), located in the vicinity of PN are in areas defined as Class 1 and Class 2 as per NPC 300. A Class 1 area can be described as a major population centre and a Class 2 area can best be described as a blend of an urban and rural area.

According to NPC 300, the One Hour L_{eq} MECP exclusionary sound level limits for a POR in a Class 1 and Class 2 area are summarized in Table 3.6, and used to assess compliance of stationary noise sources of a facility for the purposes of an ECA. These sound level limits are presented for comparison purposes only. As per NPC 300, a Plane of Window (POW) location represents a point in space corresponding with the location of the centre of a window of a noise sensitive space (typically the top storey of a dwelling is the worst-case location) and an Outdoor location represents a point within 30 m of a façade of a dwelling at a height of 1.5 m above ground. POW and Outdoor locations are located at different parts of a POR property.

Table 3.6: Sound Level Limits for Class 1 and Class 2 Areas

Time Period	Class 1 POW (Plane of Window) MECP Exclusionary Sound Level Limit (dBA)	Class 1 Outdoor MECP Exclusionary Sound Level Limit (dBA)	Class 2 POW (Plane of Window) MECP Exclusionary Sound Level Limit (dBA)	Class 2 Outdoor MECP Exclusionary Sound Level Limit (dBA)
Daytime (07:00 – 19:00)	50	50	50	50
Evening (19:00 – 23:00)	50	50	50	45
Night-time (23:00 – 07:00)	45	N/A	45	N/A

Notes:
It is understood the MECP has generally set these limits for a given classification based on a review of their research, which showed that these levels represent a level where, if a facility were to meet these limits, potential adverse effects are expected to be minimized.

Long-term unattended noise monitoring at Environmental Noise (human receptors) locations was carried out from September 25 to October 9, 2015 with approximately 275 to 330 hours of data collected at each noise monitoring location. During the long-term unattended noise monitoring program, noise data were logged continuously on an hourly basis. The long-term unattended noise monitoring locations are shown on Figure 3.14 and described in Table 3.7 (NM-1 to NM-3). For the Environmental Noise (human receptors) locations, approximately 180 to 230 hours of data were considered to be valid as some of the monitoring levels could have been impacted by inclement weather. Periods of inclement weather, unsuitable for noise measurements, were identified and excluded from the calculations. Short-term attended measurements (i.e., noise measurements ranging between 5 minutes and 30 minutes in duration) were also carried out to provide additional data for areas between long-term unattended noise monitoring locations (ANM-1 to ANM-3).

Table 3.7: Noise Monitoring Locations and Descriptions

Sampling ID	Description	MECP Classification	Receptor Type	Noise Monitoring Duration
NM-1	Residential Area (Parkham Crescent)	Class 1	Human	Long-term
NM-2	Institutional Area	Class 2	Human	Long-term
NM-3	Residential Area (Annland Street)	Class 1	Human	Long-term
ANM-1	Residential Area (Park at rear of residences)	Class 1	Human	Short-term
ANM-2	Institutional Area (open area)	Class 2	Human	Short-term
ANM-3	Residential Area (Park at rear of residences)	Class 1	Human	Short-term

Environmental noise levels vary over time and are described using an overall sound level known as the L_{eq}, or energy averaged sound level. The L_{eq} is the equivalent continuous sound level, which in a stated time, and at a stated location, has the same energy as the time varying noise level. It is common practice to measure L_{eq} sound levels in order to obtain a representative average sound level. The L_{90} is defined as the sound level exceeded for 90% of the time and typically is used as an indicator of the “ambient” noise level. A-weighted (dBA) noise levels are used to describe human responses to noise. The A-weighted equivalent continuous sound level is represented by L_{Aeq}.

The noise levels collected during the long-term unattended noise monitoring field program for the Environmental Noise (human receptors) locations are summarized in Table 3.8 to Table 3.10. Figure 3.7 to Figure 3.12 have been developed which present the minimum, maximum, average and MECP POW and Outdoor sound level limits. NPC 300 POW and Outdoor noise level limits have been included for comparison purposes only. Figure 3.13 provides the entire dataset, which includes a discrete number of periods with increased sound levels. The grey areas within Figure 3.13 represent periods of inclement weather. Noise data with the grey areas were not included in the calculation of the reported values. The results for short-term attended noise monitoring are summarized in Table 4.12.

Further to the noise data presented, during the short-term attended noise monitoring and during setup of the long-term unattended noise monitoring equipment at the Environmental Noise (human receptors) locations, it was generally observed that the local acoustic background consists of the sounds of road traffic, some contribution from activities at PN (such as standby generator testing), and activities from neighbouring sites. In areas near the shoreline, it was observed that the sounds of wave action dominate the acoustic environment. Two of the Environmental Noise human receptor locations (NM-1 and NM-2) are consistent with locations POR #2 and POR #3 from a recent noise assessments (OPG, 2019a, 2020a, 2021a), and the results are comparable.

Since there are periods of recorded maximum sound levels above the NPC 300 Class 1 and Class 2 sound level limits, noise is carried forward as a COPC in the HHRA.

Table 3.8: Environmental Noise (human receptors) – NM-1 Long-term Unattended Noise Monitoring Data Results

Time Period	L_{Aeq} (1-h)			L_{A90} (1-h)		
	Average (dBA)	Maximum (dBA)	Minimum (dBA)	Average (dBA)	Maximum (dBA)	Minimum (dBA)
Daytime (07:00 – 19:00)	54	70	44	50	66	38
Evening (19:00 – 23:00)	49	55	43	47	53	40
Night-time (23:00 – 07:00)	51	63	42	49	61	39
24h	52	70	42	49	66	38

Note:
See Table 3.6 for the reference MECP sound level limits.

Table 3.9: Environmental Noise (human receptors) - NM-2 Long-term Unattended Noise Monitoring Results

Time Period	L_{Aeq} (1-h)			L_{A90} (1-h)		
	Average (dBA)	Maximum (dBA)	Minimum (dBA)	Average (dBA)	Maximum (dBA)	Minimum (dBA)
Daytime (07:00 – 19:00)	54	62	46	50	56	43
Evening (19:00 – 23:00)	53	62	45	49	56	41
Night-time (23:00 – 07:00)	53	61	43	50	56	41
24h	54	62	43	50	56	41

Note:
See Table 3.6 for the reference MECP sound level limits.

Table 3.10: Environmental Noise (human receptors) – NM-3 Long-Term Unattended Noise Monitoring Results

Time Period	L_{Aeq} (1-h)			L_{A90} (1-h)		
	Average (dBA)	Maximum (dBA)	Minimum (dBA)	Average (dBA)	Maximum (dBA)	Minimum (dBA)
Daytime (07:00 – 19:00)	53	67	43	47	59	38
Evening (19:00 – 23:00)	47	51	39	45	50	35
Night-time (23:00 – 07:00)	49	58	36	46	54	34
24 h	52	67	36	46	59	34

Note:
See Table 3.6 for the reference MECP sound level limits.

Table 3.11: Environmental Noise (human receptors) –Short-Term Attended Noise Monitoring Results

ID	Date/Time	Height above grade (m)	L_{Aeq} (1-h) (dBA)	L_{A90} (1-h) (dBA)
ANM-1	2015-10-02 15:57 (Daytime)	4.5	52	48
ANM-2	2015-09-25 11:16 (Daytime)	4.5	56	54
ANM-3	2015-09-25 12:43 (Daytime)	4.5	48	45

Note:
See Table 3.6 for the reference MECP sound level limits.

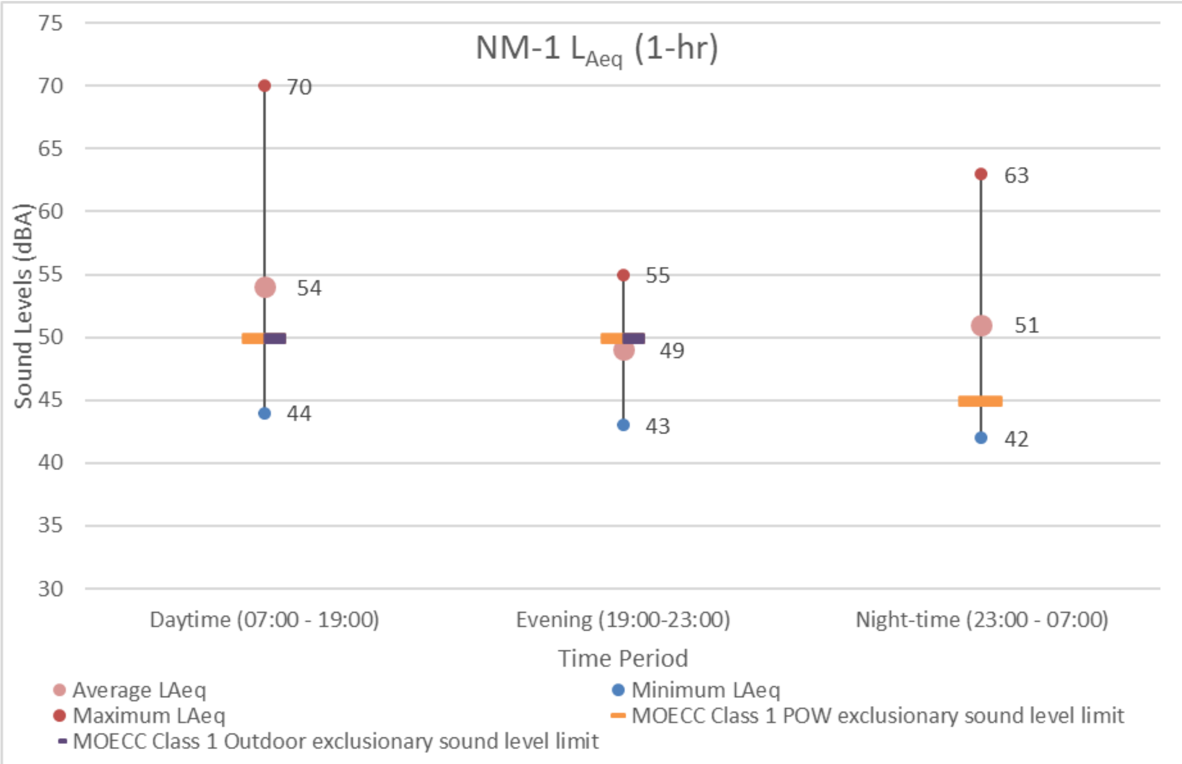


Figure 3.7: NM-1 Long-term Unattended Noise Monitoring L_{Aeq} (1-h) Overall Results

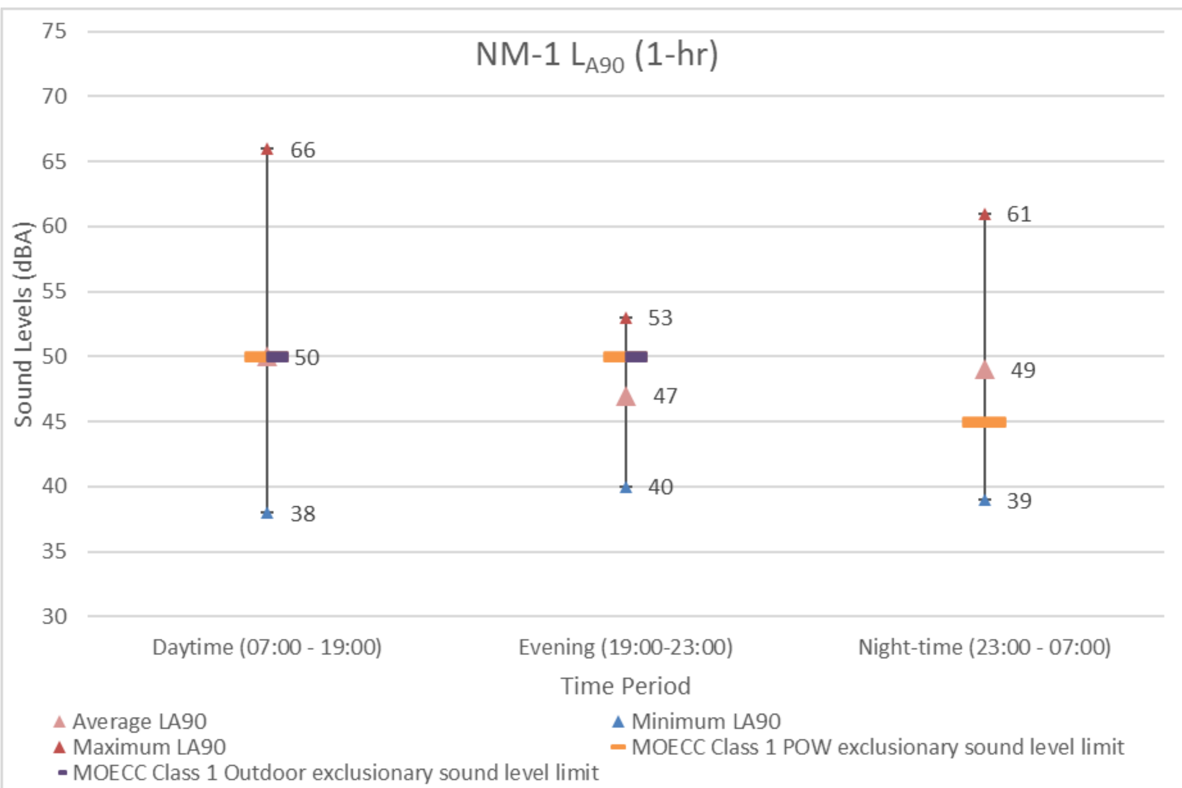


Figure 3.8: NM-1 Long-term Unattended Noise Monitoring L_{A90} (1-h) Overall Results

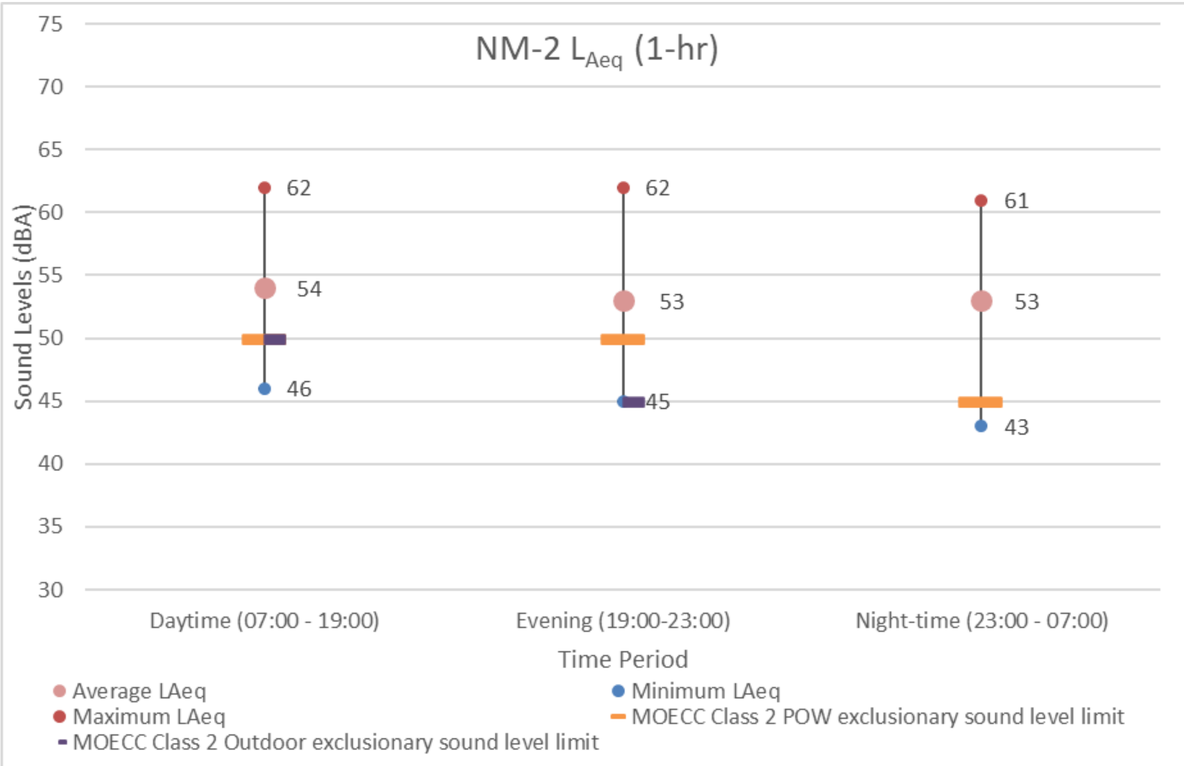


Figure 3.9: NM-2 Long-term Unattended Noise Monitoring L_{Aeq} (1-h) Overall Results

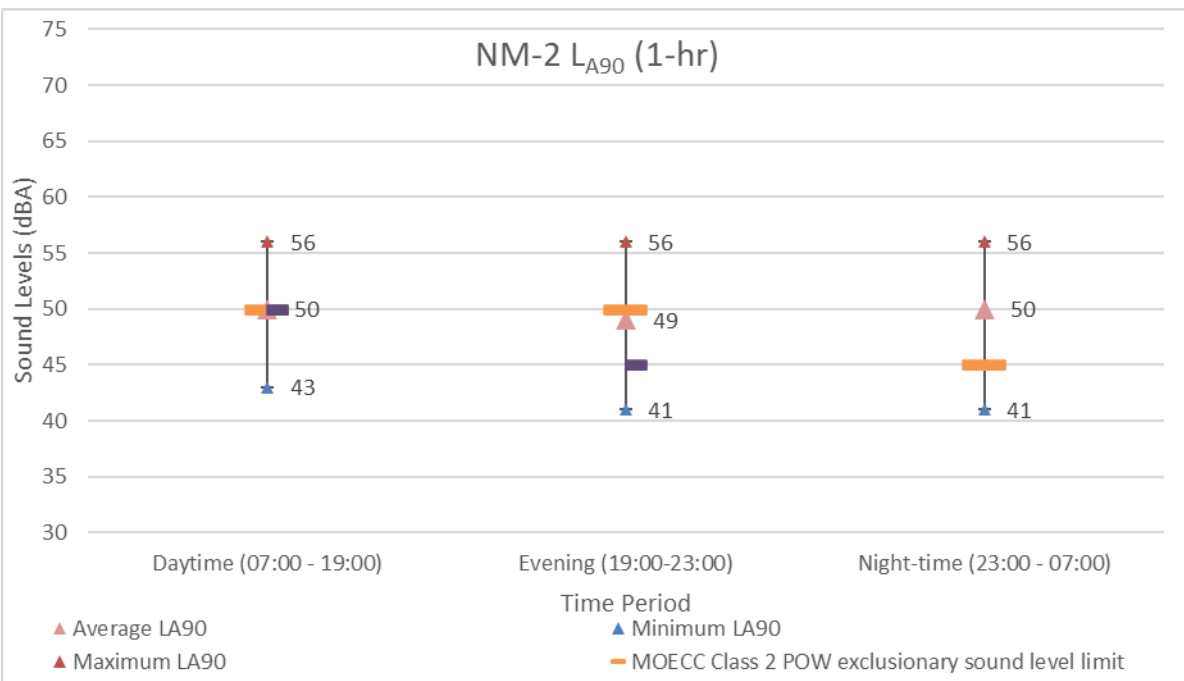


Figure 3.10: NM-2 Long-term Unattended Noise Monitoring L_{A90} (1-h) Overall Results

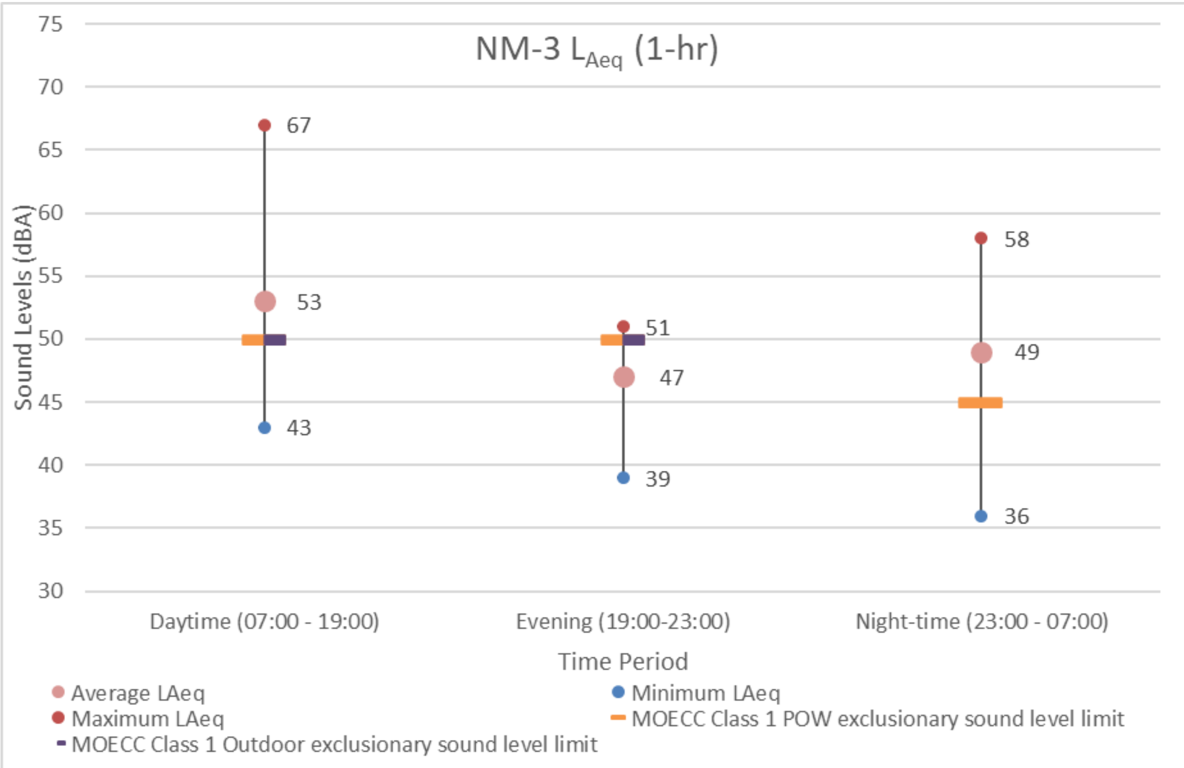


Figure 3.11: NM-3 Long-term Unattended Noise Monitoring L_{Aeq} (1-hr) Overall Results

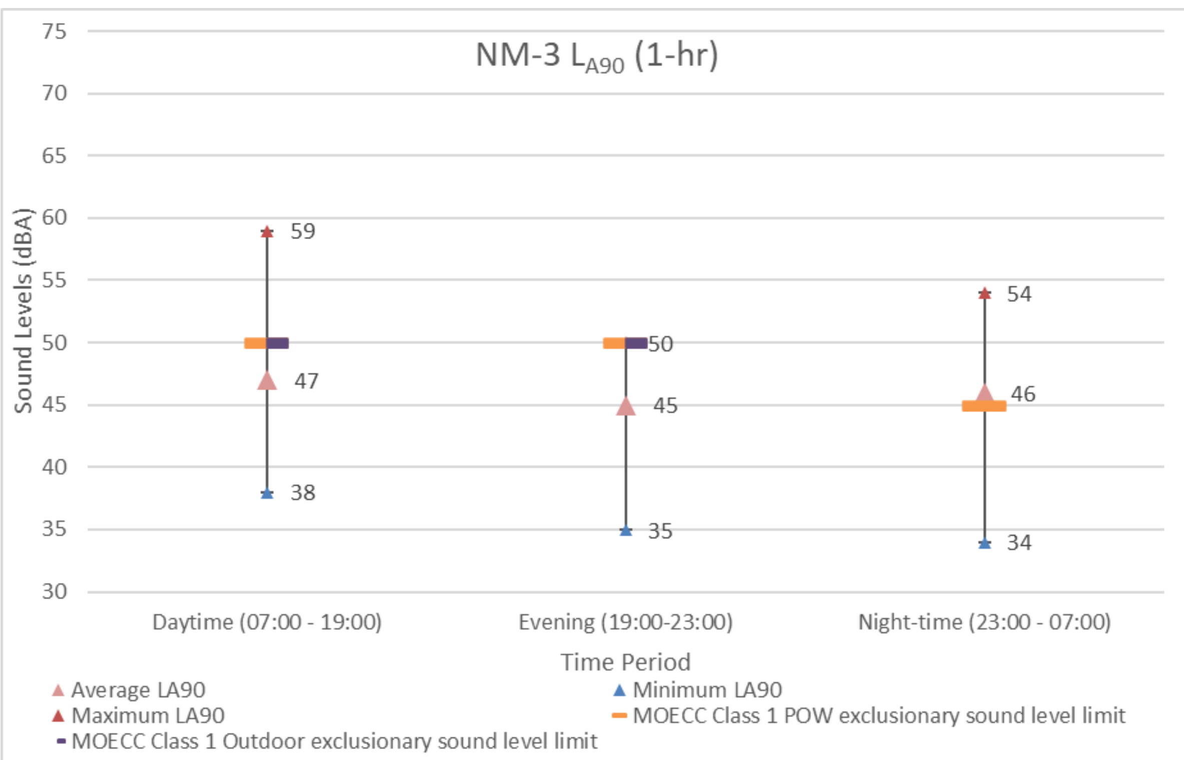


Figure 3.12: NM-3 Long-term Unattended Noise Monitoring L_{A90} (1-h) Overall Results

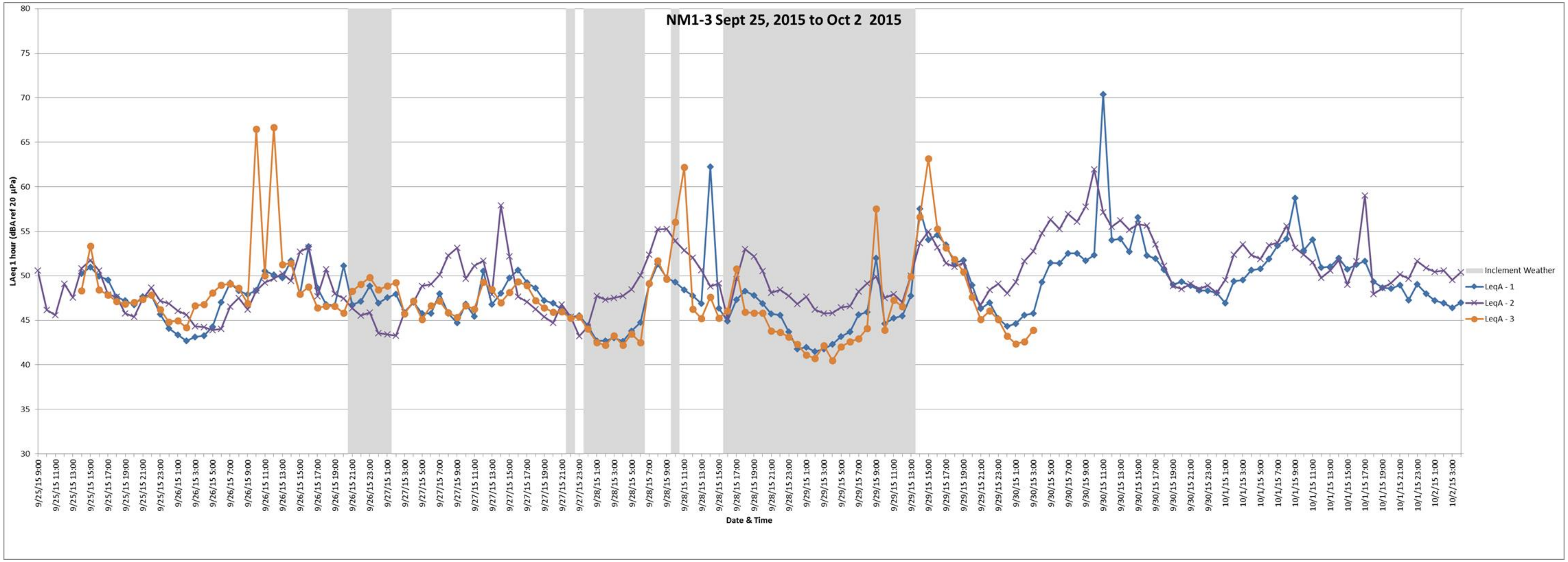


Figure 3.13: Environmental Noise Dataset (L_{Aeq} (1 h))

Figure 3.14: Environmental Noise (Human Receptors) - Long-term Unattended and Short-term Attended Noise Monitoring Locations

3.1.2.9 Summary of COPC Selection for the HHRA

Table 3.12 summarizes the radiological and non-radiological COPCs that are carried forward to the exposure assessment in the HHRA.

Table 3.12: Summary of COPCs Selected for the HHRA

Category	Radiological COPC	Non-Radiological COPC
Air	tritium, noble gases, carbon-14, radioiodines (mixed fission products), mixed beta/gamma particulates (represented by cobalt-60)	nitrogen oxides (NO_x)
Surface water	tritium, carbon-14, gross beta/gamma (represented by cesium-134)	hydrazine
Groundwater	None	None
Stormwater	None	None
Soil	cesium-134, cesium-137, cobalt-60, iodine-131, carbon-14, tritium	None
Noise	Yes	

3.1.3 Selection of Exposure Pathways

3.1.3.1 Exposure Pathways for Non-Radiological COPCs

For exposure of human receptors to non-radiological COPCs, the potential exposure pathways include:

- Ingestion of water;
- Dermal contact with water;
- Inhalation;
- Incidental ingestion of dust (inhalation), soils and sediment;
- Dermal contact with soils and sediment; and
- Ingestion of food.

Not all exposure pathways are considered complete. A complete exposure pathway consists of a contaminant source, release mechanism, transport mechanism within the relevant environmental medium (or media), point of exposure and exposure route to a receptor. Based on the COPC screening presented in Section 3.1.2, the complete exposure pathways for exposure of relevant human receptors to non-radiological COPCs generally include inhalation and ingestion, and are summarized in Table 3.13.

Hydrazine does not partition well into other environmental compartments. The environmental partitioning of hydrazine was modeled and described by Environment Canada and Health Canada (EC and HC, 2011). The modeling results show that when hydrazine is released to surface water (alkaline hardwater), it will remain almost entirely in the water (99.9% in water, 0.02% in sediment). Similarly, when hydrazine is released to air, it will remain almost entirely in air (90% in air, 9.6% in water, 0.51% in soil, and 0.01% in sediment). For hydrazine, the relevant exposure pathways for humans are ingestion (water and fish).

Table 3.13: Complete Exposure Pathways for Relevant Receptors for Exposure to Non-Radiological COPCs

Location	Receptor	Exposure Pathway	Environmental Media
Outfall (500 m S)	Sport Fisher	Inhalation	Air
		Ingestion	Aquatic animals (fish)
0.9 km NE	Industrial/Commercial Worker	Inhalation	Air
		Ingestion	Water (Ajax WSP)
1.2 km WNW	Urban Resident	Inhalation	Air
		Ingestion	Water (Ajax WSP) Aquatic animals (fish)
3.1 km NNE	Correctional Institution	Inhalation	Air
		Ingestion	Water (Ajax WSP)
6.9 km NE	Farm	Inhalation	Air
10.25 km NE	Dairy Farm	Inhalation	Air

3.1.3.2 Exposure Pathways for Radiological COPCs

For exposure of human receptors to radiological COPCs, the relevant exposure pathways include:

- inhalation of air and external exposure to air;
- ingestion of water and external exposure to water;
- incidental ingestion of soil and sediment;
- external exposure to soil and sediment; and
- ingestion of food.

The complete exposure pathways, as defined in OPG's EMP (OPG, 2021c) for exposure of relevant human receptors belonging to the six potential critical groups for PN to radiological COPCs are summarized in Table 3.14.

Although COPCs have been identified in groundwater (Section 3.1.2.4), the only groundwater operable exposure pathways for humans is through off-site dermal contact and/or incidental ingestion by recreational receptors or drinking water ingestion at the nearest water intake at the Ajax WSP. There are no groundwater supply wells downgradient of potential source areas of COPCs.

Off-site drinking water wells are influenced by the atmospheric tritium plume and this is taken into account in the public dose calculations as part of the annual EMP.

Table 3.14: Complete Exposure Pathways for Relevant Receptors for Exposure to Radiological COPCs

Receptor	Exposure Pathway	Environmental Media
Sport Fisher	Inhalation	Air
	Ingestion	Aquatic animals (fish)
	External	Air
Industrial/Commercial Worker[(1)]	Inhalation	Air
	Ingestion	Water (Ajax WSP) Soil (incidental) Sediment (incidental) Aquatic animals (fish) Terrestrial plants (local produce) Terrestrial animals (local produce)
	External	Air Water Soil Sediment
Urban Resident	Inhalation	Air
	Ingestion	Water (Ajax WSP) Soil (incidental) Sediment (incidental) Aquatic animals (fish) Terrestrial plants (local produce) Terrestrial animals (local produce)
	External	Air Water Soil Sediment
Correctional Institution	Inhalation	Air
	Ingestion	Water (Ajax WSP) Soil (incidental)
	External	Air Water Soil
Farm	Inhalation	Air
	Ingestion	Water (Wells/Ajax WSP) Soil (incidental) Sediment (incidental) Terrestrial plants (locally grown) Terrestrial animals (locally grown)
	External	Air Water Soil Sediment

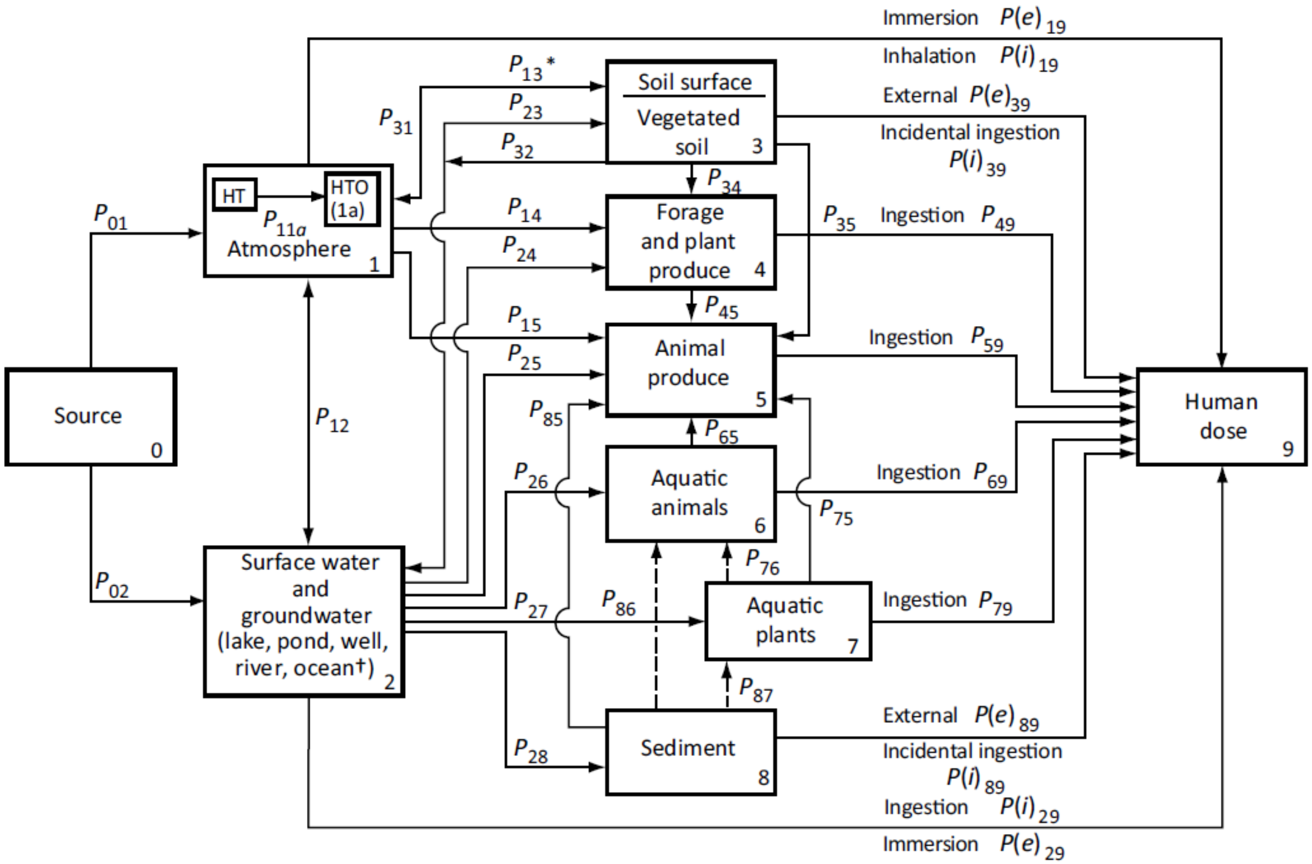
Receptor	Exposure Pathway	Environmental Media
Dairy Farm	Inhalation	Air
	Ingestion	Water (Wells) Soil (incidental) Sediment (incidental) Terrestrial plants (locally grown) Terrestrial animals (locally grown)
	External	Air Water Soil Sediment

Note:
(1) A small fraction of Industrial/Commercial workers are also Urban Residents; therefore, the ingestion pathway is included to account for when the worker is at home.

3.1.4 Human Health Conceptual Model

The conceptual model 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. 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.

A generic conceptual model, taken from CSA N288.1 is shown in Figure 3.15, and is applied to human receptors around PN. This represents the exposure pathways from source to receptor. It is appropriate for radiological and non-radiological COPCs, except that, for non-radionuclides, external and immersion pathways represent dermal exposure, and ingestion of homegrown terrestrial plants (forage and plant produce) and animal produce are not considered complete exposure pathways.



* *Includes transfer factors P_{13area}, P_{13mass}, and P_{13spw}.*

† *For ocean water, pathways P_{23}, P_{24}, P_{25}, and $P(i)_{29}$ are not used.*

Notes:

1) *The broken lines represent pathways that are not explicitly considered in the model or are considered only in special circumstances.*
2) *Factors include multiple transfers where appropriate.*

Figure 3.15: Conceptual Model for Human Receptors (CSA, 2014)

3.1.5 Problem Formulation Checklist

The information required in Health Canada's (HC, 2010) Problem Formulation Checklist has been provided in Sections 3.1.3 and 3.1.4, above.

3.1.6 Uncertainties in the Problem Formulation

The data used in the HHRA problem formulation were concluded to be of adequate quality and quantity to support the objectives of the HHRA. Maximum measured concentrations were selected for COPC screening; this is considered conservative and is not reflective of typical human exposures. The human health screening benchmarks for water were generally the lower of applicable provincial and federal drinking water standards and guidelines, which is a conservative approach, ensuring that the list of COPCs would be as comprehensive as possible. The COPC screening also considered several media as sources of potential exposure, such as air, surface water (including Lake Ontario water, effluent, and storm water), soil, ground water, and sediment. As such, the COPC screening has resulted in a conservative list of COPCs.

More generally, the HHRA problem formulation has been conservative in its assumptions to accommodate uncertainties and meet the objective of protecting human health. The conceptual model for human health is considered to be complete for the majority of general public exposures in the vicinity of the PN site. The selected receptors are expected to lead to conservative estimates of health risks and are expected to be protective of any shorter-term exposures to environmental media in the vicinity of the PN site. The selected exposure pathways are consistent with available guidance (for example, N288.1), and are expected to account for all significant exposure pathways for human receptors in the area.

There are uncertainties and conservative assumptions made in the emission estimates and operating conditions for the ESDM (Ortech, 2021):

- The highest emission rate that each source is capable of (i.e., maximum usage rates or throughputs) was used to characterize the emissions.
- All sources are assumed to be operating simultaneously at the corresponding maximum emission rate for the averaging period.
- All fuel-fired combustion equipment (i.e., comfort heating and emergency power) emission rates were determined using the highest emission factor, combined with the maximum thermal heat input or engine rating for each piece of equipment.
- Other conservative assumptions (e.g. virtual products, 100% volatilization).

Based on the conservative assumptions summarized above the emission rates used for the ESDM are not likely to be an underestimate of the actual emission rates.

3.2 Exposure Assessment

The exposure assessment for radiological COPCs follows the equations and database from CSA N288.1-14 (CSA, 2014), as required by the Pickering Licence Conditions Handbook, as well as database updates from CSA N288.1-20. The stable carbon content for carbon-14 for freshwater invertebrates was updated to the recommended value from N288.1-20 (CSA, 2020). The equations are the same between the 2014 and 2020 versions of the CSA N288.1 standard; therefore, the HHRA is compliant with both the 2014 and 2020 version of the standard.

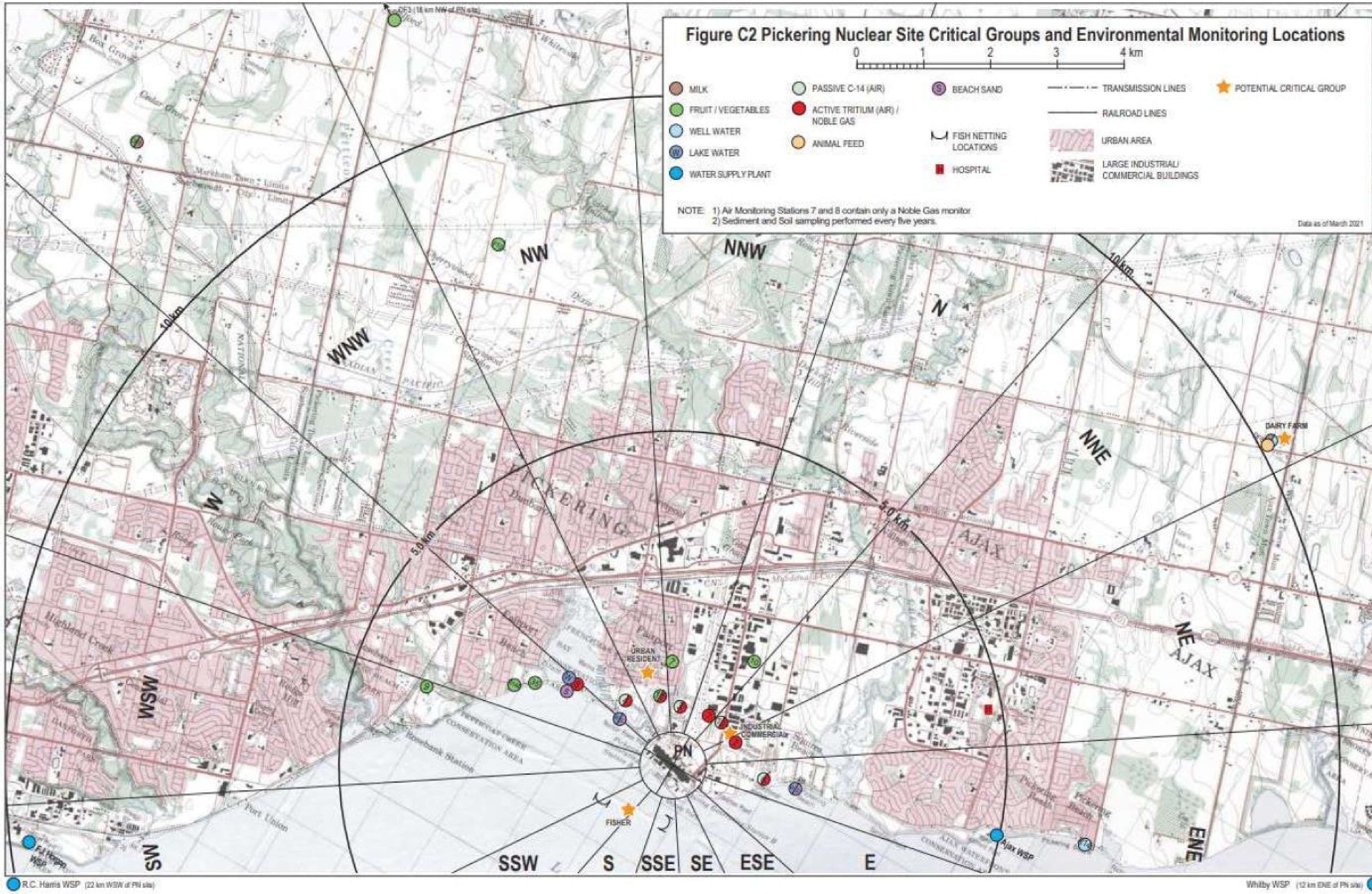
3.2.1 Exposure Locations

The exposure location is the location where the receptor comes into contact with the COPC or stressor. For both the radiological and non-radiological exposure assessment the relevant human receptors are the potential critical groups defined by the EMP, as discussed in Section 3.1.1.1. Table 3.15 and Figure 3.16 present the locations of these receptors. The approximate distance from PN is an average of the distance from PN U1-4 and U5-8 (OPG, 2017i). The exposure assessment looked at all six receptors, as reported in the EMP, where appropriate. For the non-radiological exposure assessment, the Farm and Dairy Farm potential critical groups were not assessed for water ingestion since they obtain the majority of their water intake from water wells, and not the Ajax WSP.

Table 3.15: Distance and Wind Sector of Potential Critical Groups

Potential Critical Group	Approximate Distance from PN (km)	Wind Sector (Direction to)
Sport Fisher (1)	0.5	S
Industrial/Commercial	0.95	NNE
Urban Resident	1.35	WNW
Correctional Institution (2)	3.1	NNE
Farm	6.9	NE
Dairy Farm	10.25	NNE

(1) The Sport Fisher group is located 500 m south, offshore of PN site.
(2) The Correctional Institution is the Kennedy Youth House located 3.1 km NE of PN U1-4



Source: (OPG, 2021c)

Figure 3.16: Locations of Human Receptors – Potential Critical Groups

3.2.2 Exposure Duration and Frequency

Full-time residency was assumed for the correctional institute resident, Urban Resident, Farm resident, and Dairy Farm resident. For the Industrial/Commercial worker and the Sport Fisher a residency of 23% and 1% was assumed, respectively (OPG, 2021c).

3.2.3 Exposure and Dose Calculations

3.2.3.1 Radiological Dose Calculations

Radiological dose calculations follow the equations presented in CSA N288.1-14 and N288.1-20, which are not reproduced in this report.

3.2.3.2 Non-Radiological Exposure and Dose Calculations

Air

In addressing the inhalation pathway for nitrogen oxides, only the air concentration is necessary since the hazard quotient is determined by comparing to a toxicity reference value which in the case of NO_x is a Reference Air Concentration (RfC). Therefore, dose is not calculated, and inhalation rates and body weights for receptors are not used.

Exposure to NO_x in air is assessed at the location of all potential critical groups. The estimated POI concentrations from the ESDM reports are predicted for the PN property boundary; however, a dispersion factor from the source to all potential critical groups is not available through the ESDM reports. Therefore, to estimate the concentration of NO_x in air at the potential critical group locations, the dispersion factors from IMPACT are used, as shown in Table 3.22. The dispersion factors in IMPACT were calculated as described in N288.1 for predicting atmospheric dispersion of radioactive airborne emissions from a facility, and are representative of a long-term (i.e. annual) averaging period. The dispersion factors are calculated using the sector-averaged version of the Gaussian plume model which is considered to be a conservative model for estimating long-term average air concentrations (COG, 2013; Pasquill and Smith, 1962). The maximum release rate for NO_x under normal operating conditions was 1.76 g/s from the 2020 ESDM report (Ortech, 2021). Multiplication by the dispersion factor provides an estimate of annual average NO_x at each location:

$$C_{air}\ (\mu g/m^3) = P_{01} \bullet x_0 \bullet 1E6(\mu g/g)$$

where,

P_{01}	=	transfer parameter from source to air (s/m^3)
X_0	=	emission rate (g/s)

Surface Water

The ingestion dose from exposure to hydrazine in drinking water was calculated according to the following equation, consistent with CSA N288.6-12 (CSA, 2012):

$$\text{Dose (mg/kg-d)} = C \bullet IR \bullet RAF_{GIT} \bullet D_2 \bullet D_3 \bullet D_4 / (BW \bullet LE)$$

where,

C	=	concentration of contaminant in drinking water (mg/L)
IR	=	receptor intake rate (L/d)
RAF_{GIT}	=	absorption factor from the gastrointestinal tract (unitless)
D_2	=	days per week exposed•(7 days)$^{-1}$ (d/d)
D_3	=	weeks per year exposed•(52 weeks)$^{-1}$ (wk/wk)
D_4	=	total years exposed to site (years) (for carcinogens only)
BW	=	body weight (kg)
LE	=	life expectancy (years) (for carcinogens only).

The ingestion dose from exposure to hydrazine in fish was calculated according to the following equation, consistent with CSA N288.6-12 (CSA, 2012):

$$\text{Dose (mg/kg-d)} = [\Sigma\ (C_{food\ i} \bullet IR_{food\ i} \bullet RAF_{GITi} \bullet D_i)] \bullet D_4 / (BW \bullet 365 \bullet LE)$$

where,

C_{foodi}	=	concentration of contaminant in food i (mg/kg)
IR_{foodi}	=	receptor ingestion rate for food i (kg/d)
RAF_{GITi}	=	relative absorption factor from the gastrointestinal tract for contaminant i (unitless)
D_i	=	days per year during which consumption of food i will occur (d/a)
D_4	=	total years exposed to site (years) (for carcinogens only)
BW	=	body weight (kg)
365	=	total days per year (constant) (d/a)
LE	=	life expectancy (years) (for carcinogens only)

3.2.4 Exposure Factors

3.2.4.1 Radiological Exposure Factors

For the radiological dose calculations, the exposure factors (e.g., intake rates, occupancy and shielding factors, etc.) are generally those used in CSA N288.1-14 and N288.1-20. The intake rates for ingestion and inhalation are the mean intake rates provided in CSA N288.1 and the COG DRL Guidance (COG, 2013) with the exception of the drinking water intake rate for a 1-year old infant. The drinking water intake rate for the 1-year old infant was adjusted from the default value in CSA N288.1 based on guidance in Clause 6.15.3.2, since the PN infant is assumed to drink only cow's milk (and not water and infant formula) (OPG, 2017i). Table 3.16 summarizes the exposure factors used in the radiological dose calculations that were updated for the 2019 EMP report (OPG, 2021g).

Table 3.16: Human Exposure Factors for Radiological Dose Calculations

Exposure Factor	Units(4)	Infant 1 year	Child 10 year	Adult
Inhalation rate	m^3/a	1830	5660	5950
Inhalation occupancy factor	unitless	1.0	1.0	1.0
Incidental soil ingestion rates	g dw/d	0.061	0.055	0.004
Incidental ingestion of sediment	g dw/d	0.061	0.055	0.004
Drinking water intake rate(1)	L/a	0	151.1	379.6
Aquatic animal intake rate(2)	kg/a	1.68	4.82	6.86
Terrestrial animal intake rates	kg/a	262.3	286.3	255.5
Terrestrial plant intake rates	kg/a	144.5	331.1	440
Outdoor occupancy factor	unitless	0.2	0.2	0.2
Indoor plume shielding factor (skin dose and pure beta emitters)	unitless	1.0	1.0	1.0
Indoor groundshine shielding factor (gamma emitters)(3)	unitless	0.5	0.5	0.5
Groundshine shielding factor (uneven surface shielding)	unitless	0.2	0.2	0.2
Beach swim occupancy factor	unitless	0	0.014	0.014
Bathing occupancy factor	unitless	0.014	0.014	0.014
Pool swim occupancy factor (WSP fill)	unitless	0	0.028	0.028
Pool swim occupancy factor (Well water fill)	unitless	0	0.014	0.014
Skin area	m^2	0.72	1.46	2.19
Dilution factor (DF) for shoreline sediments	unitless	1.0	1.0	1.0
Shore Width factor (lake)	unitless	0.3	0.3	0.3
Shoreline occupancy factor	unitless	0.02	0.02	0.02
No. days/a soil ingested	d/a	135	135	135
No. days/a sediment ingested	d/a	45	45	45

Notes:
(1) The infant is conservatively assessed as consuming only cow's milk which is included in the terrestrial animal intake rate.
(2) Excludes shellfish due to fresh water environment at PN. Shellfish are a marine environment food product.
(3) For effective and skin dose. For essentially pure beta emitters, this shielding factor is zero.
(4) dw used in specification of units indicates dry weight.
Sources: (COG, 2013; CSA, 2020)

3.2.4.2 Non-Radiological Exposure Factors

Based on the results of the screening, the human exposure assessment was performed for the inhalation pathway for NO_x, and the drinking water and fish ingestion pathway for hydrazine.

Air

As discussed in Section 3.2.3.2, inhalation rates and body weights for receptors are not necessary since a dose is not needed; assessment of risk from NO_x is based on the comparison of air exposure concentrations to a reference concentration.

Surface Water

For non-radiological dose calculations, exposure factors are generally those from Health Canada Preliminary Quantitative Risk Assessment guidance (HC, 2004, 2010), as recommended by Clause 6.3.5 of CSA N288.6-12 (CSA, 2012). Table 3.17 summarizes the exposure factors used in the non-radiological dose calculations.

Based on the results of the screening, the human exposure assessment was performed for hydrazine for the drinking water and fish ingestion pathways. Hydrazine is added to the feedwater for oxygen removal. Hydrazine is discharged into the aquatic environment through boiler blowdown and flushing to the intake forebay. Boiler blowdown is generally continuous and intermittent at PN U5-8, and intermittent at PN U1-4. For this assessment it was assumed that hydrazine is released to the aquatic environment continuously.

Table 3.17: Human Exposure Factors for Non-Radiological Dose Calculations

Parameter	Units	Urban Resident		Commercial /Industrial Worker	Sport Fisher		Reference
		Toddler	Adult	Adult	Toddler	Adult	
Drinking Water Intake Rate	L/d	0.6	1.5	1.5	N/A	N/A	(HC, 2021)
Fish Ingestion Rate	kg/d	0.056	0.111	N/A	0.056	0.111	(HC, 2004)
Days per Week/7 (D2)	d/d	1	1	1	N/A	N/A	(OPG, 2018d)
Weeks per Year/52 (D3)	wk/wk	1	1	0.23	N/A	N/A	(OPG, 2018d)
Years Exposed (D4)	years	N/A	80	35	N/A	35	(HC, 2021)
D_{fish}	d/a	365	365	N/A	365	365	(OPG, 2018d)
Body Weight	kg	16.5	70.7	70.7	16.5	70.7	(HC, 2021)
Life Expectancy	years	N/A	80	80	N/A	80	(HC, 2021)
$RAF_{GIThydrazine}$		1	1	1	1	1	Conservative assumption

Note:
Characteristics of the Urban Resident are also applicable to the Correctional Institution

3.2.5 Models

OPG uses IMPACT™ version 5.5.2 (IMPACT) to calculate its annual public radiological doses using a mixture of environmental monitoring data and emissions data. This version of IMPACT represents the method of dose calculation presented in CSA N288.1-14 (CSA, 2014) as well as CSA N288.1-20 (CSA, 2020).

Where environmental monitoring data were lacking, the concentration of radionuclides in air was determined from the sector-averaged Gaussian plume atmospheric dispersion model in IMPACT, based on the release rates from PN. Table 3.18 shows a summary of which radionuclides and pathways were modelled and where measured data were used.

The dispersion factors from IMPACT were also used to estimate the NO_x concentration in air at potential critical group locations.

Table 3.18: Radionuclide and pathway Data Used in the Dose Calculations

Pathway	Radionuclide	Modeled [1]	Measured
Air Inhalation	HTO	✓ (Sport Fisher)	✓[3]
	HT	✓[2]	
	C-14	✓[2]	✓
	I (mfp)	✓[2]	
	Co-60	✓[2]	
Air External Exposure	Noble Gas		✓[3]
	C-14	✓[2]	✓
	I (mfp)	✓[2]	
	Co-60	✓[2]	
Soil External Exposure	Carbon-14	✓	
	I (mfp)	✓	
	Cs-134[5], Co-60	✓	
Sand External Exposure	C-14	✓	
	Cs-134[5]	✓	
Water External Exposure (Lakes, WSPs, Wells)	HTO	✓ (wells)	✓
	C-14	✓	
	I (mfp)	✓	
	Cs-134[5]	✓	
Terrestrial Animals Ingestion	HTO	✓	✓ (milk, eggs, poultry)
	C-14	✓	✓ (milk, eggs, poultry)
	I (mfp)	✓	
	Cs-134[5], Co-60	✓	
	OBT	✓[4]	
Terrestrial Plants Ingestion	HTO		✓
	C-14		✓
	I (mfp)	✓	
	Cs-134[5], Co-60	✓	
	OBT	✓[4]	
	HTO		✓

Pathway	Radionuclide	Modeled (1)	Measured
Aquatic Animals Ingestion	C-14		✓
	I (mfp)	✓	
	Cs-134(5), Co-60		✓
	OBT	✓(4)	
Sand and Soil Incidental Ingestion	HTO	✓	
	C-14	✓	
	I (mfp)	✓ (soil)	
	Cs-134(5), Co-60	✓	✓ (sand)
Water Ingestion (WSPs, Wells)	HTO		✓
	C-14	✓	
	I (mfp)	✓	
	Cs-134(5)	✓	

Notes:
Source: (OPG, 2021c)
HTO = tritium oxide; HT = elemental tritium; OBT= organically bound tritium; mfp = mixed fission products
(1) Modeling is based on emissions or from local air measurements where they are available
(2) Concentrations are modeled from emissions and adjusted using empirical K_a determined for each potential critical group location
(3) Doses are measured directly at the site boundary and adjusted to potential critical group locations using the ratio of modeled air dispersion factors for the boundary monitor and potential critical group
(4) OBT dose is modeled from HTO concentration in terrestrial plants, terrestrial animals, or fish respectively.
(5) Cs-137 was modelled as the limiting beta-gamma radionuclide for waterborne emissions in 2016-2018 EMP reports. Cs-134 was the used in 2019-2020 after update of the DRL Report (OPG, 2017i).

3.2.6 Exposure Point Concentrations and Doses

3.2.6.1 Radiological Exposure Point Concentrations and Doses

Since 2013, the annual Radiological Environmental Monitoring Program report was changed to the annual EMP report entitled “Results of Environmental Monitoring Programs”. During this time, the EMP was redesigned to meet the requirements of CSA N288.4-10 (CSA, 2010) and expanded to include conventional contaminants, physical stressors and non-human biota; in addition to the radiological contaminants and human exposure.

For the radiological exposure assessment, exposure point concentrations are either based on measured data from the annual EMP or modelled from emissions data, as described in Table 3.18 and in the EMP report (OPG, 2021c). Additionally, when measurement averages or other calculations are performed, they are calculated using actual results obtained even if they are below the critical level (OPG, 2021c). As mentioned above, OPG uses IMPACT version 5.5.2 to calculate its annual public doses using a mixture of environmental monitoring data and emissions data.

Table 3.19 presents a summary of the annual doses reported for the potential critical groups from 2016 to 2020. Although the current PN EMP design currently focuses on the Urban Resident, Dairy Farm, Sport Fisher, and Industrial Worker, the dose for receptors at the correctional institution is also reported to show variation in dose.

Table 3.19: Summary of Dose to Potential Critical Groups from 2016-2020

Year	Age Class	Radiological Dose (µSv/a)				
		Dairy Farm	Urban Resident	Sport Fisher	Correctional Institution	Industrial Worker
2016	Adult	0.4	1.5	-	0.9	1.3
	Child	0.3	1.4	-	1.0	-
	Infant	0.3	1.4	-	-	-
2017	Adult	0.6	1.8	-	1.2	1.5
	Child	0.6	1.7	-	1.3	-
	Infant	0.8	1.7	-	-	-
2018	Adult	0.5	2.1	-	1.4	1.6
	Child	0.4	2.1	-	1.5	-
	Infant	0.4	2.0	-	-	-
2019	Adult	0.3	1.7	0.4	-	1.5
	Child	0.4	1.5	0.5	-	-
	Infant	0.5	1.7	0.4	-	-
2020	Adult	0.3	1.2	0.3	0.8	1.0
	Child	0.4	0.9	0.3	0.8	-
	Infant	0.5	1.0	0.2	-	-

Source: (OPG, 2017f, 2018h, 2019e, 2021g, 2021c)

Table 3.20 presents a summary of the maximum dose to the critical group from 2016 to 2020. The annual dose during the five-year period of interest (2016 to 2020) ranged from 1.2 to 2.1 µSv. The critical group for all years was the Urban Resident (adult). The dominant pathways and radionuclides that contribute significantly to the total dose are inhalation of tritium and external exposure to noble gases.

Table 3.20: Summary of Dose to Limiting Critical Group from 2016 to 2020

Year	Limiting Critical Group	Effective Dose (µSv)	Percentage of Regulatory Limit (%)	Percentage of Dose from Canadian Background Radiation (%)
2016	Urban Resident (adult)	1.5	0.2	0.1
2017	Urban Resident (adult)	1.8	0.2	0.1
2018	Urban Resident (adult)	2.1	0.2	0.15
2019	Urban Resident (adult)	1.7	0.2	0.12
2020	Urban Resident (adult)	1.2	0.1	0.1

Source: (OPG, 2017f, 2018h, 2019e, 2021g, 2021c)

3.2.6.1.1 Radiological Doses from the PWMF

As described in Section 3.1.2.5.1, the fields outside the PWMF are due primarily to contributions from direct gamma radiation and secondarily from gamma skyshine. The Sport Fisher is the only potential critical group where gamma radiation fields from the PWMF would likely be measurable. Based on a study from 2017 (OPG, 2018i), at a distance of 400 m from the PWMF, the measured air kerma rate was below the detection limit of 0.33 nGy/h. At a distance of 1 km from the PWMF, the air kerma rate was estimated to be negligible.

When the PWMF DSC Storage Buildings #1 to #3 are filled to capacity, the calculated dose rate at the eastern lakeside exclusion zone boundary is 7.23 x 10^{-4} µSv/hr, or 0.72 µSV per year based on 1,000 hours occupancy (OPG, 2018a). This is conservative for the Sport Fisher which is assumed to have 1% occupancy at the outfall, or 87.6 hours per year. By adjusting the occupancy to 1%, the predicted total annual dose to the Sport Fisher from the PWMF when DSC Buildings #1 to #3 are at capacity is 0.063 µSv.

Table 3.21: Dose Rate at the Exclusion Zone Boundary

Occupancy	Dose Rate - Full Capacity (µSv/h)	Annual Dose - Full Capacity (µSv)
1,000 hrs/yr (11%)	7.23 x 10^{-4}	0.72
87.6 hrs/yr (1%)	7.23 x 10^{-4}	0.063

Source: (OPG, 2018a)

3.2.6.2 Non-Radiological Exposure Point Concentrations and Doses

For the non-radiological exposure assessment, exposure point concentrations are based on the screening conducted during problem formulation, which concluded that nitrogen oxides required further assessment in air, and hydrazine required further assessment in surface water.

3.2.6.2.1 Exposure Point Concentrations in Air

Annual exposure at the potential critical group locations is based on NO_x release rates reported in the 2015 and 2017-2020 ESDM reports and dispersion factors from IMPACT. The maximum emission rate under normal operating conditions from the 2020 ESDM report is 1.76 g/s (Ortech, 2021). Applying this emission rate to the annual average dispersion factors from IMPACT results in estimated concentrations of NO_x at potential critical group locations, as shown in Table 3.22. Note that these concentrations represent annual NO_x concentrations for a steady release at 1.76 g/s.

There is uncertainty as to what the short-term air concentrations would be beyond the property boundary, as the IMPACT dispersion factors represent annual average meteorological conditions. The Sport Fisher is the closest receptor to the property boundary, located 0.5 km offshore to the south of the PN site. The Sport Fisher is located within the extended property boundary used in the ESDM report which includes areas of Lake Ontario (Figure 3.17). Therefore, the short-term air concentration at the property boundary would be considered appropriate for the Sport Fisher, with a maximum short-term exposure point concentration of 157 µg/m^3 in 2020 based on a 1-hr averaging period (Ortech, 2021). The other potential critical groups are located outside of the PN property boundary.

Table 3.22: Annual Average Exposure Point Concentrations of NO_x in Air

Potential Critical Group	Transfer Parameter from source to air, P_{01} (s/m^3)(1)	Approximate Distance from PN	Annual Average NOx Concentration ($\mu g/m^3$)
Sport Fisher	9.37E-06	0.5	16.5
Industrial/Commercial	2.02E-06	0.95	3.56
Urban Resident	9.78E-07	1.35	1.72
Correctional Institution	2.75E-07	3.1	0.484
Farm	7.67E-08	6.9	0.135
Dairy Farm	4.94E-08	10.25	0.087

(1) Transfer parameter (P_{01}) is an average of P_{01} for PN U1-4 and P_{01} for PN U5-8, reported in the 2016 DRL report (OPG, 2017i)

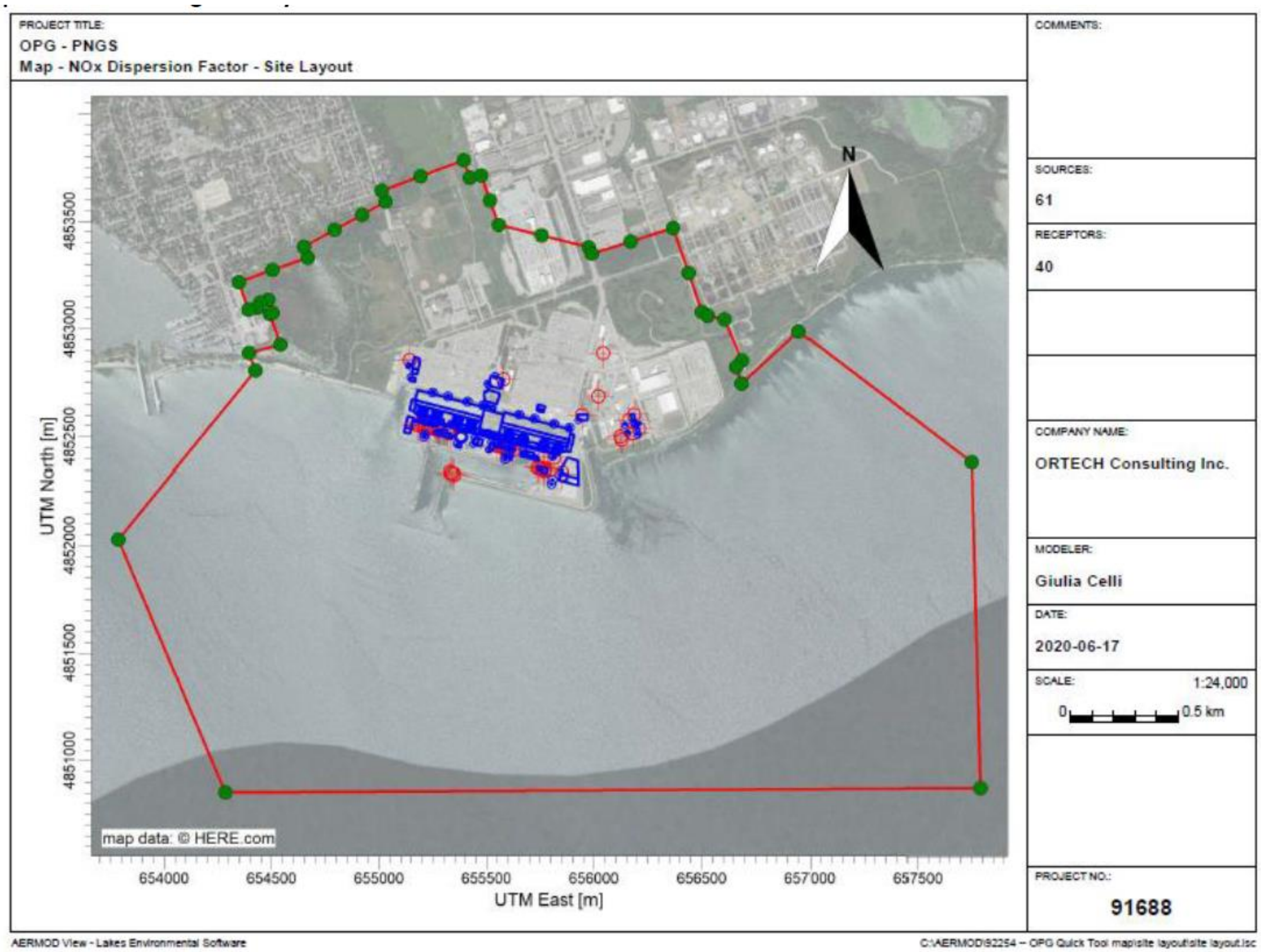


Figure 3.17: Receptor Locations Considered Along the Property Boundary and Lake Ontario

3.2.6.2.2 Exposure Point Concentrations in Water

For waterborne non-radiological COPCs, exposure point concentrations for hydrazine were determined based on measured data from the 2014 supplementary study (Ecometrix, 2015) and from weekly measured concentrations at CCW discharges collected as part of ECA requirements.

The maximum and 95% upper confidence limit of the mean (UCLM) hydrazine concentration at the outfall based on results of the 2014 supplementary study were determined from the near, mid and far-field samples taken from PN U1-4 and PN U5-8 sides. The first of three sampling events in July 2014 were used to calculate the maximum and UCLM concentrations because the other two sets of sample results were comprised mostly not detected. In the July 2014 data set, 53% of samples were below detection limits. CSA N288.6-12 suggests that data sets with greater than 50% of the data set comprising of non-detects cannot be used to calculate reliable estimates of mean and standard deviation. However, UCLM was determined using the detection limits as the sample value, which is expected to be conservative; however, the maximum value would be most applicable in this situation.

The maximum and UCLM hydrazine concentration at the outfall based on weekly CCW discharge concentrations were calculated from the combined monitoring data 2016-2020. Although 68% of the CCW samples were non-detect for hydrazine, the results were reported uncensored (i.e., results that are below the method detection limit are reported as the value generated by the analytical instrument), and the UCLM was calculated from all available values.

The maximum and UCLM hydrazine concentrations at Ajax WSP were determined using dilution factors determined from the surface water model developed for PN to support the Pickering Safe Storage Predictive Effects Assessment (PEA) (Golder and Ecometrix, 2017). For drinking water, the exposure concentration was determined using the measurements from the PN outfall stations and then applying appropriate dilution and decay rates for travel between the outfall and the WSP. The combined dilution factor from the outfall (PN U1-4 and PN U5-8) to Ajax WSP was 42. The lake conditions (i.e. water levels, water temperature, and current speeds) that were used to establish bounding conditions for the surface water model supporting the 2017 PEA were reviewed recently in a 2022 updated addendum report (Ecometrix, 2023). The review found that the differences between recent conditions over the 2016-2020 period and the conditions in 2011-2012 are minor, and that the dilution factors developed from the surface water model are still applicable for use.

In the 2014 supplementary study (Ecometrix, 2015), a dilution factor of 8, based on CSA N288.1 methodology, was used to estimate the hydrazine concentration at the Ajax WSP. This is a conservative estimate, due to conservative assumptions in the CSA aquatic dispersion model, and its parameterization for DRL purposes. As described previously, a surface water model was developed for PN to support the Pickering Safe Storage Project activities (Golder and Ecometrix, 2017). As such, the dilution factor used in the 2014 supplementary study to determine the hydrazine exposure concentration at the Ajax WSP was modified using more realistic dilution factors developed for PN to support the Pickering Safe Storage Project activities.

At a pH of 8 (representative of the typical pH observed in Lake Ontario near PN), the chemical half-life of hydrazine ranges from 0.6 to 1.31 days (EC and HC, 2011). Using the longer half-life, and a dilution factor of 42 from the outfall to the Ajax WSP, the estimated UCLM and maximum exposure concentrations at the Ajax WSP intake based on the measured lake concentrations are 0.00012 µg/L and 0.00025 µg/L, respectively.

The conditions within the Ajax WSP during water treatment favour the degradation of hydrazine. The water treatment process involves chlorinating the process water at several distinct points through the addition of sodium hypochlorite, which is an alkaline substance expected to raise the pH somewhat at those steps of the process, after which pH adjustment is undertaken through the addition of sulfuric acid (Regional Municipality of Durham, 2020). Hydrazine degradation is highly influenced by pH; alkaline conditions favour its degradation (Choudhary and Hansen, 1998). Additionally, degradation of hydrazine occurs through oxidation in the presence of oxygen; the reaction tends to be catalyzed (i.e., sped up) in the presence of certain compounds like Cu(II) and phosphate ions, which are likely to be present in some amount in drinking water. Hydrazine degradation is also favoured in the presence of organic matter, again which is likely to be present in drinking water. Hydrazine was found to decrease by more than 90% when added to chlorinated, filtered county water after 1 day (Choudhary and Hansen, 1998). As such, it was considered reasonable to assume that 90% of the starting concentration of hydrazine at the Ajax WSP intake would be degraded by the time the drinking water is used by off-site members of the public.

With a half life of 1.3 days, a dilution factor of 42 and degradation in the Ajax WSP of 90%, the estimated UCLM and maximum exposure concentrations at the Ajax WSP intake based on CCW discharge concentrations are 0.0036 µg/L and 0.048 µg/L, respectively (Table 3.23).

Table 3.23: Exposure Point Concentrations of Hydrazine in Water at the Ajax WSP

COPC	Outfall (mg/L)		Ajax WSP (mg/L)(3, 4)	
	UCLM	Max	UCLM	Max
Hydrazine (Lake Water)	1.2E-04 (1)	2.5E-04 (1)	2.2E-07	4.9E-07
Hydrazine (CCW)	1.9E-03 (2)	2.5E-02 (2)	3.7E-06	4.8E-05

Notes:
(1) UCLM and Max of PN outfall July 2014 samples (PNGSNEAR, PNGSMID, PNGSFAR in Figure 3.3) (Ecometrix, 2015). UCLM was calculated from July 2014 results only as the majority of data from August and September were non-detects.
(3) UCLM and max of weekly CCW concentrations
(4) Assumes half-life of 1.3 days, dilution factor from outfall to Ajax WSP of 42, and degradation in Ajax WSP of 90%.

3.2.6.2.3 Exposure Point Concentrations in Fish

The dose to the Sport Fisher due to ingestion of fish exposed to hydrazine assumes a continuous release. A large portion of the dataset for hydrazine were non-detects, and these concentrations were evaluated at the detection limit.

For fish ingestion, the exposure concentration was determined using all measured lake water samples collected as part of the 2014 supplementary study (Ecometrix, 2015). For exposure concentrations based on CCW discharge concentrations, a dilution factor of 4.2 was applied representing travel between the outfall (PN U1-4 and PN U5-8) and the Sport Fisher.

The fish tissue concentration for hydrazine is estimated using a bioaccumulation factor (BAF). Limited data exist on the bioaccumulation of hydrazine in aquatic organisms. A bioconcentration factor (BCF) of 288 L/kg has previously been derived based on a hydrazine concentration (144 mg/kg) estimated in guppies after four days exposure to hard water at a hydrazine concentration of 0.5 mg/L (Slonim and Gisclard, 1976). According to Environment Canada and Health Canada (EC and HC, 2011) there are limitations and uncertainties associated with this study. Hydrazine was not measured in the fish, but was estimated from measurements in water, assuming that the slightly greater loss from water over 4 days, when fish were in the water, was due to uptake into the fish. Hydrazine bioaccumulation in fish was not directly measured. Since the same study showed higher rates of hydrazine degradation due to fish excretia in water, it is not clear that any hydrazine uptake into fish actually occurred. As well, a hydrazine concentration of 0.5 mg/L can generate ecotoxicity; therefore, there is uncertainty around the BCF of 288 L/kg. According to the *Persistence and Bioaccumulation Regulations* under the *Canadian Environmental Protection Act*, hydrazine would not be considered a substance that bioaccumulates since its BAF (or BCF) is less than 5000 and its $\log K_{ow}$ is less than 5 ($\log K_{ow}$ of -2.07 (EC and HC, 2011)).

Considering the large uncertainty surrounding the Slonim and Gisclard (1976) study, the published BCF from that study was not used for the quantitative evaluation of hydrazine. Quantitative Structure-Activity Relationship (QSAR) models are available to estimate bioconcentration factors for chemicals using correlations between BCFs and hydrophobicity ($\log K_{ow}$), where experimental data on bioaccumulation are lacking (European Commission, 2006). Meylan et al. 1999 (as cited in European Commission, 2006) recommends an improved model that suggests using a logBCF of 0.5 for all non-ionic compounds with $\log K_{ow} < 1$. Therefore, a logBCF of 0.5 was used to represent bioaccumulation of hydrazine in fish.

Table 3.24: Exposure Point Concentrations of Hydrazine in Water at Sport Fisher Location

COPC	Sport Fisher Location (mg/L)(4)	
	UCLM	Max
Hydrazine (Lake Water)	1.0E-04 (1)	2.5E-04 (2)
Hydrazine (CCW)	4.5E-04 (3)	5.9E-03 (3)

Notes:

(1) UCLM of all July 2014 samples (Ecometrix, 2015). Mean was calculated from July 2014 results only as the majority of data from August and September were non-detects.

(2) Max of all 2014 samples, PNGSB NEAR in Figure 3.3 (Ecometrix, 2015)

(3) Concentration of max and UCLM CCW discharge with a dilution factor of 4.2 from outfall to Sport Fisher

3.2.7 Dose from Water and Fish Ingestion

The estimated dose to receptors due to ingestion of water from Ajax WSP and fish consumption are presented on Table 3.25 and Table 3.26, respectively. The dose from ingestion of water is not presented for the correctional institution group, because it has the same drinking water exposure factors as the Urban Resident. The dose from fish consumption is presented for the Sport Fisher and Urban Resident. Sport Fisher is assumed to obtain all fish intake near the PN site, and this is bounding for the other receptors that may also consume fish from other sources. The Urban Resident was included as it was the only other receptor group that was identified as consuming locally sourced fish (OPG, 2018d).

Table 3.25: Dose to Urban Resident and Industrial/Commercial Worker from Water Ingestion

COPC	Water Conc. From Ajax WSP (mg/L)		Urban Resident [1]				Industrial/Commercial Worker	
			UCLM Dose (mg/kg-d)		Max Dose (mg/kg-d)		UCLM Dose (mg/kg-d)	Max Dose (mg/kg-d)
	UCLM	Maximum	Toddler	Adult	Toddler	Adult	Adult	Adult
Hydrazine (Lake Water)	2.2E-07	4.9E-07	N/A[2]	4.7E-09	N/A[2]	1.0E-08	4.7E-10	1.0E-09
Hydrazine (CCW)	3.7E-06	4.8E-05	N/A[2]	7.8E-08	N/A[2]	1.0E-06	1.8E-08	2.3E-07

Notes:
(1) The dose to the Urban Resident is also applicable to the correctional institution resident.
(2) For carcinogenic substances only exposure to adult receptors is needed (HC, 2010). The toddler dose is not limiting and was not calculated.

Table 3.26: Dose to Sport Fisher and Urban Resident due to Fish Ingestion

COPC	Water Conc. at Sport Fisher Location (mg/L)		BAF[1] (L/kg fw)	Fish Tissue Concentration (mg/kg fw)		Adult Sport Fisher Dose [2] (mg/kg-d)		Adult Urban Resident Dose[2] (mg/kg-d)	
	UCLM	Maximum		UCLM	Maximum	UCLM	Maximum	UCLM	Maximum
Hydrazine (Lake Water)	9.9E-05	2.5E-04	3.16	3.1E-04	7.9E-04	2.2E-07	5.4E-07	4.3E-10	1.1E-09
Hydrazine (CCW)	4.5E-04	5.9E-03	3.16	1.4E-03	1.9E-02	2.2E-06	2.9E-05	4.4E-09	5.8E-08

Notes:
(1) The BAF is from Meylan et al. 1999 (as cited in European Commission, 2006) that suggests using a logBCF of 0.5 for all non-ionic compounds with $logK_{ow}$ < 1.
(2) For carcinogenic substances only exposure to adult receptors is needed (HC, 2010). The toddler dose is not limiting and was not calculated.

3.2.8 Uncertainties in the Exposure Assessment

Table 3.27 summarizes the major uncertainties and assumptions in the exposure assessment.

Table 3.27: Summary of Major Uncertainties in the Exposure Assessment

Risk Assessment Assumption	Justification	Over/Under Estimate Risk?
Measured concentrations of hydrazine in lake water and CCW discharges are representative of concentrations at the outfall.	Hydrazine concentrations are typically measured near their analytical method detection limits (MDL), as seen in the 2014 supplementary study results and CCW discharges which had 53% and 68% non-detect values, respectively. These values are used at MDL although there is uncertainty as to how close the non-detect values are to zero or to the detection limit.	Overestimate (Hydrazine)
Water concentration for hydrazine at Ajax WSP is pre-treatment, and is modeled from liquid releases.	Hydrazine degrades rapidly under chlorinated conditions typically used for treatment/distribution of drinking water (EC and HC, 2011). No information on concentration of other COPCs post WSP treatment, dilution factor available from PN to Ajax WSP.	Overestimate (Hydrazine)
Average dilution factors from the surface water model were used to estimate water concentrations at the Ajax WSP.	Based on maximum and minimum lake water conditions the dilution factors from PN to Ajax WSP can range from 14 to 873, with an average dilution factor of 42.	Neither
Dilution factors developed to estimate water concentrations were based on lake data collected from 2011-2012.	The lake conditions (i.e. water levels, water temperature, and current speeds) that were used to establish bounding conditions for the surface water model supporting the 2017 PEA were reviewed recently in a 2022 updated addendum report (Ecometrix, 2023). The review found that the differences	Neither

Risk Assessment Assumption	Justification	Over/Under Estimate Risk?
	between recent conditions over the 2016-2020 period and the conditions in 2011-2012 are minor, and that the dilution factors developed from the surface water model are still applicable for use.	
Mixed beta-gamma emissions to air (particulate) are represented by cobalt-60 and mixed beta-gamma emissions to water are represented by cesium-134.	These radionuclides are the radionuclides with the most limiting dose based on DRL calculation.	Overestimate
BAF for hydrazine is based on QSAR model and not measured bioaccumulation data.	Limited information exists on bioaccumulation of hydrazine, although it is expected to be low. Only one study (Slonim and Gisclard, 1976) exists on hydrazine bioaccumulation, and there is large uncertainty surrounding the methods and results.	Neither (value is best estimate)
It was assumed that 90% of hydrazine in surface water will degrade during the water treatment process.	Hydrazine has been shown to degrade readily under specific aquatic environmental conditions including those in chlorinated water treatment systems under alkaline conditions. (Choudhary and Hansen, 1998). These conditions are expected to be present at the Ajax WSP which supplies drinking water to the Urban Resident, Correctional Institution Resident and Commercial/Industrial Worker.	Neither (value is best estimate)

3.3 Toxicity Assessment

3.3.1 Toxicological Reference Values (TRVs)

A summary of the TRVs selected for the COPC in air – nitrogen oxides – is presented in Table 3.28 and discussed below.

The ECCC (2017) 1-hour and annual CAAQS for nitrogen dioxide (NO_2) were selected as Reference Air Concentrations (RfCs) for nitrogen oxides (NO_x). Note that nitrogen oxides (NO_x) are defined as the sum of nitrogen dioxide (NO_2) and nitric oxide (NO). Emissions of NO_x consist mainly of NO, with some NO_2. In ambient air, NO converts rapidly to NO_2. NO_2 has adverse health effects at much lower concentrations than NO. Therefore, air quality guidelines are typically based on the health effects of NO_2.

Health Canada conducted a review to support the development of a CAAQS for NO_2 (HC, 2016). Based on evidence from epidemiological and animal toxicology studies, linking ambient concentrations of NO_2 pollution to a wide range of health effects Health Canada (2016) concluded the following:

- there is strong evidence that ambient NO_2 causes both short-term and long-term respiratory effects (e.g., asthma), and short-term mortality; as well as suggestive evidence linking it to a wide range of other adverse health outcomes;
- these effects have been observed in epidemiological studies at NO_2 concentrations that commonly occur in Canada;
- in studies examining the shape of the concentration–response curve, there is an approximately linear relationship between ambient NO_2 concentrations and health effects, with no clear evidence of a threshold; hence, based on the balance of the evidence it should be assumed that any increment in levels of ambient NO_2 presents an increased risk for health effects, up to and including mortality;
- the health evidence supports the establishment of both short-term and long-term standards to protect against the full suite of health effects associated with ambient NO_2.

As a result of these findings, (ECCC, 2017) selected a CAAQS for 1-hour exposure based on an upper bound value of ambient 1-hour average NO_2 concentrations in Canada, and a CAAQS for annual average exposure based on the annual average of 1-hour average NO_2 concentrations (Table 3.28).

Table 3.28: Selected Human Toxicity Reference Values for Chemical COPCs in Air

COPC	Averaging Period	TRV Type	Value	Reference
Nitrogen oxides	1-hour	2020 CAAQS (Nitrogen Dioxide)	113 µg/m^3 (60 ppb)	(ECCC, 2017)
	Annual	2020 CAAQS (Nitrogen Dioxide)	32 µg/m^3 (17 ppb)	(ECCC, 2017)

The TRV selected for hydrazine in water is presented in Table 3.29. Hydrazine is classified by the International Agency for Research on Cancer (IARC) as a Group 1A carcinogen and the US EPA as a Group B2 carcinogen – probable human carcinogen; and by the European Commission as Category 2 for carcinogenicity – should be regarded as if it is carcinogenic to man. Studies showed tumor induction in mice, rats and hamsters following administration of hydrazine via inhalation (1.3 and/or 6.5 mg/m^3) and in mice treated orally (1.87 mg/kg bw/day) (EC and HC, 2011). The US EPA (1991) has derived an oral slope factor of 3.0 (mg/kg-day)$^{-1}$ for human ingestion of hydrazine based on a 1970 study by Biancifiori on liver cancer in mice exposed to hydrazine sulphate orally.

Table 3.29: Selection Human Toxicity Reference Values for Chemical COPCs in Water

COPC	TRV Type	Value	Units	Reference
Hydrazine	Oral Slope Factor	3	(mg/kg/d)$^{-1}$	IRIS U.S. EPA, 2001 (as cited in U.S. EPA, 2009)

3.3.2 Radiation Dose Limits and Targets

The public dose limit for radiation protection is 1 mSv/a, as described in the Radiation Protection Regulations under the *Nuclear Safety and Control Act*. This limit is defined as an incremental dose. It is set at a fraction of natural background exposure to radiation. Public doses arising from licensed facilities are compared to the public dose limit and higher doses are considered unacceptable.

3.3.3 Uncertainties in the Toxicity Assessment

Oral slope factors, such as that for hydrazine, are developed as conservative upper-bound estimates of the increase in carcinogenic risks due to lifetime exposure to the COPC. Slope factors are used to estimate an upper bound probability of an individual developing cancer as a result of exposure to a particular level of a potential carcinogen. The slope factor is based on the assumption of a linear low-dose response. This is considered conservative.

3.4 Risk Characterization

3.4.1 Risk Estimation for Non-Radiological COPCs

In order to characterize potential risks quantitatively, the results of the exposure and toxicity assessments were used to estimate dose or concentration-based hazard quotients (HQs) and incremental lifetime cancer risks (ILCRs) for each receptor. HQs were estimated for non-carcinogenic substances using a threshold TRV as follows:

$$\text{Hazard Quotient} = \text{Estimated Exposure} / \text{Toxicity Reference Value}$$

These HQs were compared to an acceptable value of less than 0.2, as recommended by Clause 6.5.2.6 in CSA N288.6-12.

For carcinogenic substances, the estimated exposure was multiplied by the appropriate non-threshold TRV, either a slope factor or a unit risk, to derive a conservative estimate of the potential ILCR, as follows:

$$\text{ILCR} = \text{Estimated Exposure} \times \text{Cancer Slope Factor}$$

The estimated ILCRs were compared to a target cancer risk of 1 in 1,000,000 or 10^{-6}, as recommended by Clause 6.5.2.4 in CSA N288.6-12. This level is consistent with the acceptable risk level used by the Ontario MECP (MECP, 2011) and the US EPA (2005). At this risk level, health impacts are considered to be negligible. Other agencies, such as Health Canada use a target cancer risk of 1 in 100,000 or 10^{-5}. However, a range of cancer risk levels between 1 in 10,000 and 1 in 1,000,000 may be considered acceptable (HC, 2010).

3.4.1.1 Estimated Risk due to Inhalation

A summary of the concentration-based HQs for NO_x inhalation is presented in Table 3.30. The HQs are only calculated for the potential critical groups based on annual average air concentrations. The estimated exposures are discussed in the exposure assessment in Section 3.2. The TRVs used are those from Table 3.28 in the toxicity assessment in Section 3.3.

There is also a TRV available for 1-hr NO_x of 113 $\mu g/m^3$; however, the 1-hr NO_x concentrations could only be calculated for the Sport Fisher as short-term concentrations or dispersion factors for all potential critical groups are not available in the ESDM reports. Since the Sport Fisher is located at the outfall, the property boundary concentration is appropriate as a conservative assumption for the Sport Fisher. Conservatively, it was assumed that the Sport Fisher would be exposed to the maximum 1-hr concentration at the PN property boundary of 157 $\mu g/m^3$ under normal operating conditions. Therefore, the short-term HQ for the Sport Fisher is 1.4. An HQ based on short-term exposure, cannot be calculated for the other potential critical groups.

Table 3.30: Annual Average Hazard Quotients for Inhalation of NO_x in Air

Potential Critical Group	Hazard Quotient
Sport Fisher	5.2E-03
Industrial/Commercial	1.1E-01
Urban Resident	5.4E-02
Correctional Institution	1.5E-02
Farm	4.2E-03
Dairy Farm	2.7E-03

Notes:
The Sport Fisher and Industrial/Commercial potential critical groups are assumed to spend 1% and 23% of their time, respectively, at their locations. This has been factored into the HQ calculation.

3.4.1.2 Estimated Risk due to Ingestion of Water and Fish

A summary of the ILCRs for exposures to hydrazine are presented in Table 3.31 and Table 3.32. The HQs and ILCRs are calculated according to the equations described above. The estimated doses are from Table 3.25 and Table 3.26 in the exposure assessment in Section 3.2. The TRVs used are those from Table 3.29 in the toxicity assessment in Section 3.3.

Table 3.31: Incremental Lifetime Cancer Risk for Ingestion of Water

Potential Critical Group	Hydrazine (Ajax WSP sourced from Lake Water)		Hydrazine (Ajax WSP sourced from CCW)	
	UCLM	Maximum	UCLM	Maximum
Industrial/Commercial	1.4E-09	3.1E-09	5.3E-07	7.0E-07
Urban Resident	1.4E-08	3.1E-08	2.3E-07	**3.0E-06**
Correctional Institution	1.4E-08	3.1E-08	2.3E-07	**3.0E-06**

Notes:
Grey shading and bold font indicate when the risk exceeds ILCR > 1E-06.

Table 3.32: Incremental Lifetime Cancer Risk for Ingestion of Fish

Potential Critical Group	Hydrazine (Lake Water)		Hydrazine (CCW)	
	UCLM	Maximum	UCLM	Maximum
Sport Fisher	6.5E-07	**1.6E-06**	**6.7E-06**	**8.7E-05**
Urban Resident	1.3E-09	3.3E-09	1.3E-08	1.7E-07

Notes:
Grey shading and bold font indicate when the risk exceeds ILCR > 1E-06.

3.4.2 Risk Estimation for Radiological COPCs

For radionuclides, the total dose is compared to the public dose limit of 1 mSv/a as discussed in Section 3.2.6.1 above.

3.4.3 Discussion of Chemical and Radiation Effects

3.4.3.1 Effects Monitoring Evidence

Two studies of health indicators in Durham Region (DRHD, 1996, 2007) compared the incidence of cancer deaths and birth defects for Durham Region, and for municipalities within Durham Region including Ajax-Pickering, Oshawa-Whitby, Clarington, and North Durham against the same statistics for the Province of Ontario. In the 1996 study, Halton Region and Northumberland were used for comparison purposes and in the 2007 study Halton Region and Simcoe County were used for comparison against Durham Region. Both studies found no evidence that any emissions from CANDU stations at PN or Darlington Nuclear Generating Station had any adverse health effects on nearby residents.

In an additional study in 2013, cancer risk in Pickering residents due to tritium exposure from PN was studied (Wanigaratne et al., 2013). In order to determine whether tritium was associated with cancers that can be caused by radiation exposure, the tritium concentration in air was estimated based on an atmospheric dispersion model. It was found that tritium estimates were not associated with increased risk of radiation-sensitive cancers in Pickering.

Recently, population health assessments have been conducted by the Region of Durham, focusing on analysis by Health Neighbourhood, presenting a broad range of health data. PNGS falls within the Frenchman's Bay Health Neighbourhood (P1) which includes areas to the south of Highway 401 around Frenchman's Bay. Compared to the Region of Durham, residents in this Health Neighbourhood have similar or lower rates for health indicators such as asthma, diabetes, lung disease and cardiovascular disease. The population residing in Health Neighbourhood P1 are generally found to be doing similar or better in terms of health compared to the rest of Durham region (DRHD, 2017).

3.4.3.2 Likelihood of Effects

3.4.3.2.1 Air - Inhalation

For air inhalation exposures, potential non-carcinogenic effects attributed to nitrogen oxides were evaluated for all potential critical groups, as shown in Table 3.30. Estimated hazard quotients for the potential critical groups based on modelled annual average concentrations, were below 0.2.

The estimated short-term hazard quotient for the Sport Fisher exceeds the acceptable level of 0.2 based on a modelled 1-hr NO_x concentration during normal operations (HQ=1.4). The modelled concentrations used to quantify short-term inhalation risk represent the highest POI concentrations for nitrogen oxides that could result from the maximum emission rates generated at PNGS. Although the maximum emission rates are conservative, there is evidence that ambient nitrogen oxide (NO_2) can cause short-term adverse health effects (HC, 2016).

There is uncertainty around the short-term (1-hour) air concentrations that have been applied to estimate risk for the Sport Fisher. The maximum POI concentration reported in the ESDM report (Ortech, 2021) represents the highest concentration that may be expected at the property boundary; however the Sport Fisher's location is approximately 0.5 km offshore where a greater degree of dispersion from the source may take place.

There is also uncertainty around the short-term air concentrations at potential critical group locations, and therefore risks were not quantified for the other receptors. Since other potential critical groups are located outside of the boundary used to determine the POI concentration, it is anticipated that the hazard quotient for the other receptors will be lower than that for the Sport Fisher.

3.4.3.2.2 Surface Water – Drinking Water Ingestion

As shown in Table 3.31, the incremental lifetime cancer risk due to exposure to hydrazine from drinking water at Ajax WSP for the Urban Resident, Correctional Institution resident, and Industrial/Commercial worker are below the acceptable risk level of one in a million. This is based on a measured lake water concentrations collected during the 2014 supplemental investigation (Ecometrix, 2015), adjusted by a dilution factor and taking into account the upper limit half-life of 1.3 days for hydrazine in lake water and 90% degradation of hydrazine in the Ajax WSP.

The same analysis, using measured CCW concentrations from the PN U1-4 and PN U5-8 outfall, shows an incremental lifetime cancer risk for the Urban Resident and Correctional Institution resident using maximum concentrations, but risks were acceptable when using the UCLM concentration at the outfall. The UCLM concentrations are more appropriate for the assessment of the drinking water pathway for hydrazine, since receptors would be exposed to an averaged concentration over the course of a year.

3.4.3.2.3 Surface Water – Fish Ingestion

As shown on Table 3.32, exposure to the UCLM hydrazine concentration for the Sport Fisher through fish ingestion is below the acceptable cancer risk level of 10^{-6}. Since fish are mobile, exposure to the UCLM hydrazine concentration is more realistic than exposure to the maximum. The maximum would be above the acceptable cancer risk level of 10^{-6}. The maximum risk estimate is conservative. The fish tissue concentration was estimated based on measured hydrazine concentrations in the PN outfalls, and an assumed BAF for hydrazine.

The same analysis, using UCLM CCW concentrations of hydrazine from the PN U1-4 and PN U5-8 outfall resulted in an ILCR 6.7 times greater than the acceptable cancer risk level. This finding is based on conservative exposure assumptions for the Sport Fisher; the Sport Fisher is assumed to consume 100% of their fish diet from those collected in the vicinity of PNGS. Realistically, a fisher would likely visit and harvest fish from various locations throughout the year including those unaffected by PN emissions.

There was no risk to the Urban Resident for hydrazine due to fish consumption, since locally sourced fish represents a negligible (0.2%) proportion of the fish in their diet (OPG, 2017i).

3.4.3.3 Radiation Effects

The public dose estimates for the critical group (Industrial/Commercial worker or the Urban Resident) are approximately 0.1% to 0.2% of the regulatory public dose limit of 1 mSv/a and approximately 0.1% to 0.15% of the dose from Canadian background radiation. Since the critical group receives the highest dose from PN, demonstration that they are protected implies that other receptor groups near PN are also protected.

The Sport Fisher may receive a maximum dose up to 0.063 µSv/a from exposure to the PWMF (Phase I and Phase II) at full capacity (i.e., DSC Storage buildings #1, 2 and 3 are filled). The dose to the Sport Fisher from existing PN operations is between 0.2 and 0.5 µSv/a (Table 3.19); therefore, the total dose from PN operations and the PWMF may be up to 0.57 µSv/a; however, this is still a small fraction of the regulatory public dose limit.

Facility releases are considered to be adequately controlled, and further optimization of PN operations is not required. Nevertheless, the ALARA principle is applied at PN to reduce emissions as low as reasonably possible.

Since the dose estimates are a small fraction of the public dose limit and natural background exposure, no discernable health effects are anticipated due to exposure of potential groups to radioactive releases from PN.

3.4.3.4 Noise Effects

The 2018-2020 Acoustic Assessment Report (OPG, 2019a, 2020a, 2021a) prepared for PN demonstrate that PN operates in compliance with applicable MECP noise limits. The 2018 Acoustic Assessment Report was reviewed and approved by the MECP. In issuing the latest amended ECA No. 2372-BESHSC for PN site in 2019, the MECP verified that the findings of the Acoustic Assessment Report adequately demonstrate that PN does not cause a substantial noise impact at the identified PORs.

Although there are periods of recorded maximum sound levels above the MECP NPC 300 Class 1 and Class 2 sound level limits, site observations indicate these are unlikely to be directly associated with PN activities. These elevated sound levels are likely the result of localized events such as road traffic or human activity in the vicinity of the noise monitoring locations. It is common for noise levels in populated urban areas, such as near the PN site, to occasionally exceed the applicable prescribed sound level limit. As these occasional periods of elevated sound levels are not likely associated with PN activities, it is not expected that noise from PN activities is having a direct adverse effect on human receptors near the PN site.

3.4.4 Uncertainties in the Risk Characterization

There is inherent uncertainty in the air model in IMPACT that is used by OPG to estimate atmospheric dispersion factors to the potential critical group locations. Uncertainty in the air predictions arises from the following assumptions made in the model (COG, 2013):

- The activity in the plume has a normal distribution in the vertical plane.
- The effects of building-induced turbulence on the effective release height and plume spread have been generalized, while data suggest that effects of building wakes vary substantially depending upon the geometry of the buildings and their orientation with respect to wind direction.
- A given set of meteorological and release conditions leads to a unique air concentration, where in reality measured concentrations can vary by a factor of 2 under identical conditions.

At distances greater than 1 km, there is a two-fold uncertainty around the predictions of the sector-averaged Gaussian model used in IMPACT (COG, 2013). At all distances, the Gaussian air model in IMPACT on average, overpredicts air concentrations by approximately a factor of 1.5 (COG, 2013). Considering the combined uncertainties in the exposure assessments and the target values, it is reasonable that the overall risks presented are conservative estimates.

The UCLM concentrations of hydrazine measured from lake water and from CCW measurements differ by approximately 1.5 orders of magnitude which represents an uncertainty as to which data set is more representative of the hydrazine concentrations expected at the outfall. Many of the measurements at the CCW were below detection limit, and as such the lower range of concentrations from the PN discharge is not well defined. Uncensored data was used to calculate UCLM concentrations, which should not bias the value greatly; however, there is uncertainty in the data set which routinely hovers near the analytical detection limit. Although risks were identified to human receptors through exposure to CCW discharge concentrations, conservative exposure assumptions have been used for the HHRA and these would likely offset the identified risks under a realistic exposure scenario. Lake water concentrations were collected on three individual sampling events and may not capture potential temporal variability. As such there is value in considering both sets of data for the HHRA.

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.

4.0 Ecological Risk Assessment

4.1 Problem Formulation

The Problem Formulation defines the problem to be addressed in the EcoRA and the framework and general methodology by which the EcoRA will address the defined problem (FCSAP, 2012). Consistent with the FCSAP (2012), the problem formulation typically includes the following elements:

- A description of the EcoRA objectives or management goals;
- A description of the regulatory context of the EcoRA;
- A review of existing Study Area information;
- The selection of COPCs;
- The selection of Valued Ecosystem Components (VECs) that may be present in the Study Area;
- A description of the exposure pathways by which COPCs in the Study Area may come into contact with the VECs,
- An ecological conceptual model (CSM) that illustrates the connections between the sources of contaminants, the exposure pathways and VECs;
- An explanation of protection goals;
- Identification of assessment endpoints and measurement endpoints;
- The development of lines of evidences for each assessment endpoint and how the measurement endpoints will be used to evaluate risk to VECs;
- How risks will be characterized; and
- The description of any uncertainties associated with the Problem Formulation.

These elements are discussed in the following sections. During the problem formulation stage, decisions are made on which COPCs and receptors should be further evaluated in the EcoRA. During this planning stage, no conclusions are made regarding effects.

The EcoRA focuses on the PN site and surrounding area, as shown in Figure 4.1. The assessment has been divided into nearshore Lake Ontario (generally in the area surrounding the PN outfalls), the PN site, and Frenchman's Bay.

Figure 4.1: Area of Assessment for Ecological Risk Assessment

4.1.1 Receptor (VEC) Selection and Characterization

4.1.1.1 Receptor (VEC) Selection

It is an impractical task to assess the effect of radiological and non-radiological emissions on all the species of biota within the natural ecosystem on the PN site. Therefore, a select group of organisms are chosen for dose and risk analysis. These organisms are selected because they are known to exist on the site, represent major taxonomic/ecological groups, represent major pathways of exposure, have ecological significance, or have important intrinsic or economic value. These organisms are also known as valued ecosystem components (VECs). The list of selected VECs should be sufficiently broad, such that protection of the VECs should provide reasonable assurance that all species within the ecosystem are protected. The model used for assessment of dose and risk is either specific to the selected VEC species, or is a more generic biota assessment model that is appropriate to a number of VECs with similar exposure characteristics.

VECs have been selected in previous ecological assessments for the PN site in 2000 (SENES, 2000a) and 2007 (SENES, 2007e). For the 2000 ERA, VECs were selected based on a review of biota found on or near the site, and multi-stakeholder input. In 2007, the VEC list was revised, with rationale provided. For this ERA, the ecological receptors considered in past ERAs, along with their rationale, were reviewed and supplemented with recent information to arrive at an appropriate selection of VECs. The rationale for selection is presented on Table 4.1. Recent available information on the terrestrial and aquatic communities are found in species lists (Beacon, 2020a), biodiversity monitoring reports (Beacon, 2017b, 2017a, 2018, 2019, 2020b), impingement monitoring reports (OPG, 2017d, 2018f, 2019c, 2020c, 2021f), vegetation mapping, and incidental observations of wildlife, summarized in Sections 2.3.5 and 0, respectively.

In addition, OPG sought input from the Williams Treaties First Nations representatives on VEC selection in July 2021. The VECs assessed in the previous 2017 ERA were presented, along with lists of other species observed in the study area over the 2016-2020 period. The goal was to obtain feedback on whether there are species of interest to the Williams Treaties First Nations for inclusion in the ERA. Input regarding the selection of VEC species were considered in the selection rationale in Table 4.1. A representative of Williams Treaties First Nations suggested two VEC options based on prevalence in Lake Ontario – the inclusion of Round Goby instead of Brown Bullhead, and the assessment of zebra mussels instead of benthic invertebrates. During the VEC selection process the risk assessors concluded that assessment of the Brown Bullhead (selected as a native species) will be protective of the Round Goby (not selected, as it is an introduced invasive species). The suggestion to assess zebra mussels was also considered, and the risk assessors concluded that the assessment of benthic invertebrates, which is intended to represent both sensitive and resilient aquatic organisms, would be protective of zebra mussels. Additionally, zebra mussels in Lake Ontario are considered an invasive species. OPG acknowledges that the ERA was completed from a Western scientific perspective, and that it may not fully address the impact on Indigenous inherent and treaty rights as they are understood today. OPG is working with the Williams Treaties First Nations to have more fulsome and ongoing engagement on future ERAs.

For consistency across assessments, VECs that were selected for the 2017 ERA were selected, unless a rationale for removal or replacement of the VEC was identified through recent information. The presence and abundance of species that are discussed on Table 4.1 are generally based on species classifications on the current 2020 PN Species List (Beacon, 2020a), for which the study area includes the entire PNGS property, Alex Robinson Park, Hydro Marsh, and species observed on or off Lake Ontario, offshore from the study area.

VECs were selected as receptors for the conceptual model based on the criteria on Table 4.1, which are guided by the criteria for receptor selection identified in N288.6-12 (CSA, 2012). The species listed in bold on Table 4.1 were selected as VECs. 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. For example, the Alewife and Emerald Shiner are similar across all criteria and could be assessed interchangeably. In the 2017 ERA, the Alewife has been selected as a VEC as the dominant species impinged at PN. However, during the current ERA update, the Emerald Shiner was selected as the VEC in place of Alewife, in order to address recommendations by ECCC to evaluate the area of thermal effects on Emerald Shiner habitat (OPG, 2018j). Any effects on the Emerald Shiner are considered representative of those for Alewife. Further description regarding the chosen VECs, such as habitat and feeding habits, are provided in Appendix B.

Table 4.2 shows the VECs chosen for assessment and the assessment models used in estimating their COPC exposure, dose and risk. Nine species of fish were chosen as VECs to represent the fishes likely to be influenced by the operation of PN. However, due to the limited species-specific exposure factor and toxicity data available, risks to fish are estimated by assessing the fish in two categories (bottom-dwelling fish and pelagic fish) for the radiological assessment, and as one category (all fish) for the non-radiological assessment, using generic exposure and dose assessment models. When measured data were available (i.e. white sucker), fish were assessed at the species level and not as a generic category. Similarly, a generic exposure and dose assessment model was applied for all terrestrial plants using generic bioaccumulation factors and toxicity reference values.

A fish model is used for assessment of frogs because the sensitive life stages for frogs (i.e., egg and tadpole) are aquatic and similar to the sensitive life stages for fish. For example, during the tadpole stage, tadpoles and fish have similar exposure pathways (e.g., absorption through skin and gills). In addition, exposure factor and toxicity data for amphibians are limited. Therefore, the fish assessment model is considered to be appropriate for frogs during their sensitive life stages.

A fish model is also used for assessment of turtles, since there is a lack of exposure factor and toxicity data for turtles. Both organisms reside in water, and they share similar exposure pathways.

Protection of the VECs implies that other species in the same taxonomic ecological group or VEC category are also protected.

Table 4.1: Criteria to Select Ecological Receptors (VECs)

Organism Category	Species (Potential VEC)	Selection Criteria				Outcome of Selection (Rationale)
		1	2	3	4	
		Major Plant or Animal Group (representing main exposure pathways, feeding habitats, and/or habitats on the Site	**Facility, Stakeholder or Indigenous Significance** (incl. abundance)	**Socio-Economic or Ecological Significance**	**Exposed to and/or Sensitive to Stressor**	
Aquatic Invertebrates	**Benthic Invertebrates**	▪ Benthic invertebrate	▪ VEC for the 2017 ERA	▪ Food source for other ecological receptors	▪ Exposed to waterborne emissions through surface water and sediment	**Selected as VEC (1,2,3,4)**
Mollusc	Zebra Mussels *(Dreissena polymorpha)*	▪ Freshwater mussel	▪ Abundant near the Site ▪ Identified as of interest by communities	▪ Introduced aquatic invasive species	▪ Exposed to waterborne emissions through surface water and sediment	Not selected. Assessment of benthic invertebrates considered protective of zebra mussels.
Aquatic Plants	**Narrow-leaved Cattail** *(Typha angustifolia)*	▪ Aquatic plant	▪ Abundant in wetland habitat and in drainage ditches near PNGS ▪ VEC for the 2017 ERA	▪ Native species ▪ Used by red-winged blackbird for nesting ▪ Food source for other ecological receptors	▪ Exposed to waterborne emissions through surface water and sediment ▪ Sensitive to radioactive emissions ▪ Has potential to accumulate contaminants	**Selected as VEC (1,2,3,4)**
Amphibians and Reptiles	**Midland Painted Turtle** *(Chrysemys picta marginate)*	▪ Turtle	▪ Present on Site (Hydro Marsh and Frenchman's Bay) [2] ▪ VEC for the 2017 ERA	▪ Special Status (COSEWIC)	▪ Exposed to waterborne emissions through surface water and sediment	**Selected as VEC (1,2,3,4)**
	Northern Leopard Frog *(Lithobates pipiens)*	▪ Frog	▪ Present on Site (ditches, wetlands, cultural meadow) [2] ▪ VEC for the 2017 ERA	▪ N/A	▪ Exposed to waterborne emissions through surface water and sediment	**Selected as VEC (1,2,4)**
Benthic Fish	**American Eel** *(Anguilla rostrata)*	▪ Benthic predator fish ▪ Invertivore/carnivore	▪ Present on Site ▪ VEC for the 2017 ERA	▪ Native species ▪ Not on SARA Schedule 1 (under consideration for addition) ▪ Threatened (COSEWIC) ▪ Endangered (SARO)	▪ Exposed to waterborne emissions through water, sediment, and diet. ▪ Periodically impinged.	**Selected as VEC (1,2,3,4)**
	Brown Bullhead *(Ameiurus nebulosus)*	▪ Benthic forage fish ▪ Found in nearshore to inshore waters ▪ Invertivore/herbivore/ carnivore	▪ Abundant near the Site. [1] ▪ VEC for the 2017 ERA ▪	▪ Native species ▪ Lake Ontario commercial and recreational fish species	▪ Exposed to waterborne emissions through water, sediment, and diet. ▪ Sensitive to thermal emissions and impingement concerns.	**Selected as VEC (1,2,3,4)**
	Round Goby *(Neogobius melanostomus)*	▪ Benthic forage fish ▪ Common prey fish ▪ Invertivore	▪ Abundant near the Site ▪ Identified as of interest by communities	▪ Introduced aquatic invasive species	▪ Exposed to waterborne emissions through water, sediment, and diet.	Not Selected. Assessment of Brown Bullhead is preferred as it is a native species. Protection of Brown Bullhead will be protective of the Round Goby.
	Round Whitefish *(Prosopium cylindraceum)*	▪ Benthopelagic forage fish ▪ Found in nearshore to offshore waters ▪ Benthivore	▪ Lake-wide fish that may feed and reproduce near the Site [3] ▪ Reported in Fish Community Objectives for Lake Ontario as a species targeted for protection and restoration ▪ VEC for the 2017 ERA	▪ Native species ▪ Recreational fish species ▪ Commercially harvested in Ontario jurisdiction of Lake Ontario prior to approximately 2011	▪ Exposed to waterborne emissions through water, sediment, and diet. ▪ Sensitive to thermal stressors and impingement concerns	**Selected as VEC (1,2,3,4)**

Organism Category	Species (Potential VEC)	Selection Criteria 1 **Major Plant or Animal Group** (representing main exposure pathways, feeding habitats, and/or habitats on the Site	2 **Facility, Stakeholder or Indigenous Significance** (incl. abundance)	3 **Socio-Economic or Ecological Significance**	4 **Exposed to and/or Sensitive to Stressor**	Outcome of Selection (Rationale)
	White Sucker *(Catostomus commersonii)*	▪ Common benthic forage fish ▪ Found in nearshore to inshore waters ▪ Invertivore/detritovore	▪ Ubiquitous in L. Ontario ▪ VEC for the 2017 ERA	▪ Native species ▪ Recreational and baitfish in Ontario	▪ Exposed to waterborne emissions through water, sediment, and diet. ▪ Sensitive to thermal emissions and impingement concerns. ▪ Preferred species for monitoring due to abundance	**Selected as VEC (1,2,3,4)**
Pelagic Fish	Alewife *(Alosa pseudoharengus)*	▪ Pelagic forage fish (near/offshore, planktivore) ▪ Common prey fish	▪ Lake-wide fish that may feed and reproduce near the Site ▪ VEC for the 2017 ERA	▪ N/A	▪ Exposed to waterborne emissions through water and diet. ▪ Most impinged species	Not Selected. Assessment of the Emerald Shiner will be protective of the Alewife.
	Emerald Shiner *(Notropis atherinoides)*	▪ Pelagic forage fish (near/offshore, planktivore) ▪ Common prey fish	▪ Lake-wide fish that may feed and reproduce near the Site	▪ Native species ▪ Baitfish in Ontario	▪ Exposed to waterborne emissions through water and diet. ▪ Sensitive to thermal emissions and impingement	**Selected as VEC (1,2,3,4)**
	Lake Trout *(Salvenlinus namaycush)*	▪ Pelagic predator fish ▪ Found in nearshore to offshore waters ▪ Piscivore	▪ Lake-wide fish that may feed and reproduce near the Site ▪ VEC for the 2017 ERA	▪ Native salmonid species ▪ Recreational fish species	▪ Exposed to waterborne emissions through water and diet. ▪ Sensitive to thermal emissions, and impingement concerns.	**Selected as VEC (1,2,3,4)**
	Northern Pike *(Esox lucius)*	▪ Pelagic predator fish ▪ Found in nearshore to inshore shallow waters ▪ Piscivore	▪ Present near the Site ▪ VEC for the 2017 ERA	▪ Native species ▪ Recreational and commercial fish species on Ontario waters of Lake Ontario	▪ Exposed to waterborne emissions through water and diet.	**Selected as VEC (1,2,3,4)**
	Smallmouth Bass *(Micropterus dolomieu)*	▪ Pelagic predator fish ▪ Found in nearshore to inshore shallow waters ▪ Piscivore/invertivore	▪ Present near the Site ▪ VEC for the 2017 ERA	▪ Native species ▪ Recreational fish species	▪ Exposed to waterborne emissions through water and diet. ▪ Sensitive to thermal emissions, and impingement concerns.	**Selected as VEC (1,2,3,4)**
	Walleye *(Stizostedion vitreum)*	▪ Benthopelagic predator fish ▪ Found in nearshore to inshore waters ▪ Piscivore	▪ Present near the Site ▪ VEC for the 2017 ERA	▪ Native Species ▪ Recreational and commercial fish species in Ontario jurisdiction of Lake Ontario	▪ Exposed to waterborne emissions through water and diet.	**Selected as VEC (1,2,3,4)**
Riparian Birds	Black-crowned Night Heron *(Nycticorax nycticorax)*	▪ Wading bird ▪ Piscivore / carnivore	▪ Migratory species; breeds at PN; scarce ▪ Observed in Frenchman's Bay and Hydro Marsh	▪ N/A	▪ Exposed to waterborne emissions through surface water, sediment and prey.	Not Selected. Assessment of other riparian piscivores (such as the Common Tern) will be protective of this species.
	Bufflehead *(Bucephala albeola)*	▪ Diving duck ▪ Invertivore	▪ Migratory species; overwinters/breeds at PN ▪ VEC for the 2017 ERA	▪ Food source for other VECs (i.e. red fox)	▪ Exposed to waterborne emissions through surface water, sediment and prey.	**Selected as VEC (1,2,4)**
	Common Tern *(Sterna hirundo)*	▪ Aerial diver ▪ Piscivore / invertivore	▪ Migratory species; breeds at PN (at least 96 nests observed in 2020) ▪ VEC for the 2017 ERA	▪ Breeding habitat at PNGS	▪ Exposed to waterborne emissions through surface water, sediment and prey.	**Selected as VEC (1,2,4)**

Organism Category	Species (Potential VEC)	Selection Criteria 1 Major Plant or Animal Group (representing main exposure pathways, feeding habitats, and/or habitats on the Site	2 Facility, Stakeholder or Indigenous Significance (incl. abundance)	3 Socio-Economic or Ecological Significance	4 Exposed to and/or Sensitive to Stressor	Outcome of Selection (Rationale)
	Double-Crested Cormorant *(Phalacrocorax auratus)*	▪ Diving bird ▪ Ground-nesting piscivore	▪ Migratory species ▪ Nests on vertical structures in the forebay	▪ Breeding species within wetlands	▪ Exposed to waterborne emissions through surface water, sediment and prey.	Not selected. Assessment of other riparian piscivores (such as the Common Tern) will be protective of this species.
	Least Bittern *(Ixobrychus exilis)*	▪ Heron ▪ Ground-nesting piscivore	▪ Migratory species ▪ Rare at PN but observed once in 2020	▪ Threatened (COSEWIC and SARA)	▪ Exposed to waterborne emissions through surface water, sediment and prey.	Not selected. Assessment of other riparian piscivores (such as the Common Tern) will be protective of this species.
	Lesser Scaup *(Aythya affinis)*	▪ Diving duck ▪ Invertivore	▪ Migratory species ▪ Uncommon at PN	▪ N/A ▪	▪ Exposed to waterborne emissions through surface water, sediment and prey.	Not selected. Assessment of other riparian ducks (i.e. Bufflehead) will be protective of this species.
	Ring-billed Gull *(Larus delawarensis)*	▪ Riparian bird ▪ Consumes fish, insects, mammals	▪ Present on Site year-round; breeding habitat ▪ VEC for the 2017 ERA	▪ N/A	▪ Exposed to airborne emissions through soil and prey ▪ Exposed to waterborne emissions through surface water, sediment and prey	**Selected as VEC**
	Trumpeter Swan *(Cygnus buccinators)*	▪ Aquatic bird ▪ Nests in marshes and ponds ▪ Consumes aquatic plants	▪ Present on Site year-round; breeding habitat ▪ Identified as significant species in previous ERAs	▪ N/A	▪ Exposed to waterborne emissions through surface water, sediment and prey.	**Selected as VEC (1,2,4)**
Riparian Mammals	**Muskrat** *(Ondatra zibethicus)*	▪ Small riparian herbivore ▪ Consumes aquatic plants	▪ Present on Site year-round; resides in Hydro Marsh / found in ditches ▪ VEC for 2017 ERA	▪ Food source for other ecological receptors	▪ Exposed to waterborne emissions through surface water, sediment, and diet	**Selected as VEC (1,2,4)**
Terrestrial Invertebrates	**Earthworm**	▪ Terrestrial invertebrate	▪ VEC for the 2017 ERA	▪ Food source for other ecological receptors	▪ Exposed to airborne emissions through soil	**Selected as VEC (1,2,3,4)**
Terrestrial Plants	Butternut *(Juglans cinerea)*	▪ Deciduous tree	▪ Present on-Site	▪ Endangered (COSEWIC and SARO)	▪ Exposed to airborne emissions and contaminated soil	Not selected; assessment of the Red Ash is expected to be protective of the Butternut tree
	Chokecherry (*Prunus virginiana ssp. virginiana*)	▪ Shrub	▪ Present on-Site ▪ VEC for the 2017 ERA	▪ Native species	▪ Exposed to airborne emissions and contaminated soil	**Selected as VEC (1,2,4)**
	Eastern Hemlock (*Tsuga canadensis*)	▪ Coniferous Tree	▪ Present on-Site ▪ VEC for the 2017 ERA	▪ Native species	▪ Exposed to airborne emissions and contaminated soil	**Selected as VEC (1,2,4)**
	New England Aster (*Symphyotrichum novae-angliae* formerly *Aster novae-angliae*)	▪ Herbaceous perennial	▪ Present on-Site ▪ VEC for the 2017 ERA	▪ Native species	▪ Exposed to airborne emissions and contaminated soil	**Selected as VEC (1,2,4)**
	Pines (various)	▪ Coniferous Tree	▪ Present on-Site ▪ VEC for the 2017 ERA	▪ Native species	▪ Exposed to airborne emissions and contaminated soil	**Selected as VEC (1,2,4)**
	Red Ash (*Fraxinus pennsylvanica*)	▪ Deciduous tree ▪ Found in mixed forest areas	▪ Present on-Site ▪ VEC for the 2017 ERA	▪ Native species	▪ Exposed to airborne emissions and contaminated soil	**Selected as VEC (1,2,4)**

Organism Category	Species (Potential VEC)	Selection Criteria 1 **Major Plant or Animal Group** (representing main exposure pathways, feeding habitats, and/or habitats on the Site	2 **Facility, Stakeholder or Indigenous Significance** (incl. abundance)	3 **Socio-Economic or Ecological Significance**	4 **Exposed to and/or Sensitive to Stressor**	Outcome of Selection (Rationale)
	Sandbar Willow (*Salix exigua*)	▪ Woody shrub ▪ Found near shorelines	▪ Present on-Site ▪ VEC for the 2017 ERA	▪ Native species ▪ Provides nesting habitat for birds	▪ Exposed to airborne emissions and contaminated soil	**Selected as VEC (1,2,4)**
Terrestrial Birds	Great Horned Owl	▪ Nest in forested areas ▪ Consumes mammals, birds	▪ Scarce at the site ▪ Non-migratory	▪ Breeds in the area	▪ Exposed to airborne emissions, contaminated soil, waterborne emissions through surface water and diet	Not selected. Assessment of the Red-tailed hawk is expected to be protective of the Great Horned Owl.
	Grey Catbird *(Dumetella carolinensis)*	▪ Found in terrestrial and riparian edge habitats ▪ Consumes invertebrates, insects	▪ Migratory species; common [1] ▪ Common near PNGS	▪ Breeds in the area	▪ Exposed to airborne emissions, contaminated soil, waterborne emissions through surface water and diet	Not selected. Assessment of the Red-Winged Blackbird is expected to be protective of the Grey Catbird.
	Red-winged Blackbird	▪ Found in marshes, along waterways ▪ Consumes insects	▪ Migratory species ▪ Abundant at the Site	▪ Breeds in the area	▪ Exposed to airborne emissions, contaminated soil, waterborne emissions through surface water and diet	**Selected as VEC (1,2,4)**
	Red-tailed Hawk	▪ Found in open habitats ▪ Consumes small mammals and birds	▪ Migratory species ▪ Common at the Site	▪ Breeds in the area	▪ Exposed to airborne emissions, contaminated soil, waterborne emissions through surface water and diet	**Selected as VEC (1,2,4)**
	Barn Swallow	▪ Aerial insectivore	▪ Recently observed at the Site; 35 active nests recorded in 2020	▪ Threatened (COSEWIC, SARA)	▪ Exposed to airborne emissions, waterborne emissions through surface water and diet	Not selected. Assessment of the Red-Winged Blackbird is expected to be protective of the Barn Swallow.
	Chimney Swift	▪ Aerial insectivore	▪ Large flocks observed over the Site but likely do not breed at the Site	▪ Threatened (COSEWIC, SARA)	▪ Exposed to airborne emissions, waterborne emissions through surface water and diet	Not selected. Assessment of the Red-Winged Blackbird is expected to be protective of the Chimney Swift.
	Peregrine Falcon	▪ Found on shorelines and cliff habitats ▪ Consumes birds	▪ Migratory species ▪ Seen on and nearby the site but no active onsite nests since 2019	▪ Previously observed to breed in the area	▪ Exposed to airborne emissions, contaminated soil, waterborne emissions through surface water and diet	Not selected. Assessment of the Red-tailed hawk is expected to be protective of the Peregrine Falcon.
Terrestrial Mammals	**Meadow Vole**	▪ Small mammalian herbivore ▪ Common assessment model	▪ Abundant/common at the PN site	▪ Breeds in the area	▪ Exposed to airborne emissions, contaminated soil, waterborne emissions through surface water and diet	**Selected as VEC (1,2,4)**
	Red Fox	▪ Mammalian omnivore ▪ Common assessment model	▪ Uncommon at the PN site ▪ Potentially breeds near the Site and is present year-round	▪ Breeds in the area	▪ Exposed to airborne emissions, contaminated soil, waterborne emissions through surface water and diet	**Selected as VEC (1,2,4)**
	White-Tailed Deer	▪ Large mammalian herbivore ▪ Common assessment model	▪ Uncommon at the PN site ▪ Potentially breeds near the Site and is present year-round	▪ Breeds in the area	▪ Exposed to airborne emissions, contaminated soil, waterborne emissions through surface water and diet	**Selected as VEC (1,2,4)**

Table Sources:
[1] Current Species List (Beacon, 2020a)
[2] 2007 ERA (SENES, 2007e)

Table 4.2: Summary of VECs and their Assessment Models used in the EcoRA

VEC Category	Assessment Model	VEC
Aquatic Invertebrates	Benthic Invertebrate	Benthic Invertebrates
Aquatic Plants	Aquatic Plant	Narrow-leaved Cattail
Amphibians and Reptiles	Benthic Fish[2]	Midland Painted Turtle
		Northern Leopard Frog
Fish	Benthic Fish	American Eel
		Brown Bullhead
		Round Whitefish
		White Sucker
	Pelagic Fish	Emerald Shiner
		Lake Trout
		Northern Pike
		Smallmouth Bass
		Walleye
Riparian Birds	Trumpeter Swan	Trumpeter Swan
	Ring-billed Gull	Ring-billed Gull
	Common Tern	Common Tern
	Bufflehead	Bufflehead
Riparian Mammals	Muskrat	Muskrat
Terrestrial Invertebrates	Soil Invertebrate	Earthworms
Terrestrial Plants	Grass/Shrub	Chokecherry
		New England Aster
		Sandbar Willow
	Pine	Eastern Hemlock
		Pine
		Red Ash
Terrestrial Birds	Red-winged Blackbird	Red-winged Blackbird
	Red-tailed Hawk	Red-tailed Hawk
Terrestrial Mammals	Red Fox	Red Fox
	Meadow Vole	Meadow Vole
	White-Tailed Deer	White-Tailed Deer

Note:
1 Species in bold in Table 4.1 were selected as VECs. Table 4.2 indicates their VEC category, and the dose assessment model that was used to estimate their COPC exposures.
2 A fish model was used to assess amphibians and reptiles.

Flying insects may be adult forms of aquatic insects or terrestrial insects, the latter consisting of those insects that emerge from soil and those that spend their early life stages on foliage. The relative abundance of each will vary with location and time of the year. In this ERA, the Red-winged Blackbird was selected to represent a terrestrial insectivorous bird species. The Red-winged Blackbird is assumed to consume earthworms because data for the flying insect to bird pathway is limited whereas that for the earthworm to bird is much better defined. Further, the consumption of earthworms by the Red-winged Blackbird instead of flying insects is a conservative approach since earthworms generally have higher contaminant concentrations than adult (flying) insects.

4.1.1.2 Consideration of Species at Risk

A review of all flora and fauna identified in the PN Site Study Area (Beacon, 2017b, 2017a, 2018, 2019, 2020a, 2020b) was performed against the Species at Risk in Ontario (SARO) list, the SARA (Schedule 1) list and the COSEWIC list for threatened or endangered species. Consistent with the information presented on Table 2.13 (Plant Species at Risk), Table 2.15 (Terrestrial Species at Risk), and Table 2.16 (Fish Species at Risk), a number of threatened and endangered species have been identified within the PN Site Study Area. The species which are considered for the EcoRA and during the 2016 to 2020 time period, as shown in Table 4.3 do not include historical SAR observations that have not been confirmed in recent years, since routine monitoring has demonstrated that the PN site is no longer providing habitat for these species. These include three plant species (Slender bush-clover, Kentucky coffee tree, Red mulberry; not observed since 2000), three bird species (Common Nighthawk, Bobolink and Bank Swallow; not observed since 2006-2010), and one fish (Lake Sturgeon, not observed since 2005). These historical observations were discussed in Sections 2.3.5.5, 2.3.5.6.2 and 2.3.6.3.

Species at Risk can be assessed using representative species already selected for the EcoRA.

Butternut was identified in as being located in the Fresh-Moist Sugar Maple – Hemlock Mixed Forest ELC (TRCA, 2009a); and the presence of Butternut trees was last identified on the PN site in 2020 in Alex Robertson Park at the entrance to the trail from the parking lot off of Sandy Beach Road (Beacon, 2020b). Red Ash is also a deciduous tree and can represent Butternut in the assessment.

Barn Swallow is confirmed breeding on site. 35 active nests were present in 2020 divided between inside the Protected Area (20) and south side of Protected Area (15). Four Chimney Swift were observed over the Protected Area in June 19, 2020, and large flock was observed feeding over Alex Robertson Park (Beacon, 2020b). The Red-winged Blackbird was selected as a representative species for all terrestrial insectivores, and would conservatively represent Barn Swallow and Chimney Swift for chemical and radiological exposures.

Least Bittern was last observed on the PN site in 2020 breeding in Hydro Marsh (Beacon, 2020b). The Common Tern can represent the Least Bittern in the assessment as a riparian bird that ingests fish and insects.

Although Blanding's Turtle has not been observed since 2006, their presence in Frenchman's Bay has not been ruled out as targeted surveys have not been conducted for turtles. The Midland Painted Turtle can represent Blanding's Turtle in the assessment as a species that may be present in Frenchman's Bay.

Table 4.3: Representative Species for Identified Species at Risk

Species at Risk (Common and Scientific Name)	**Federal and Provincial Status**	**Representative Species**	**Last Observed** (Beacon, 2020b; OPG, 2021f)
Blanding's Turtle (*Emydoidea blandingii*)	Threatened (provincial), Endangered (federal)	Midland Painted Turtle	2006
Barn Swallow (*Hirundo rustica*)	Threatened (federal)	Red-winged Blackbird	2020
Chimney Swift (*Chaetura pelagica*)	Threatened (federal and provincial)	Red-winged Blackbird	2020
Least Bittern (*Ixobrychus exilis*)	Threatened (federal and provincial)	Common Tern	2020
Butternut (*Juglans cinerea*)	Endangered (federal and provincial)	Red Ash	2020
American Eel (*Anguilla rostrata*)	Endangered (provincial), Under Review (federal) Threatened (COSEWIC)	American Eel	2020

4.1.1.3 Receptor (VEC) Characterization

Receptor profiles in Appendix B describe the habitat and the feeding habits of the selected receptor species. The receptor species were assigned to assessment locations on the site based on habitat features at each location and where the receptor is likely to be found. Receptor locations for assessment purposes are discussed in Section 4.1.5.

For mammals and birds, dietary assumptions were made based on the described feeding habits. Diets were simplified to represent the main food chain pathways without trying to capture their full taxonomic complexity. For example, Muskrats are assumed to eat aquatic plants. Additionally, although some species may primarily eat insects (i.e., Red-winged Blackbird), earthworm is used as a surrogate for all insects and invertebrates, since limited data are available for insects and other invertebrates. The dietary assumptions for bird and mammal receptors are detailed in Table 4.17.

Species-specific exposure parameters, including bioaccumulation factors, food and water ingestion rates, transfer factors and body weights, are described in Section 4.2.3.4.

4.1.2 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 EcoRA are presented in Table 4.4.

Measurement endpoints are conceptually related to assessment endpoints and are defined as the tools that are used to measure exposure of or 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 benthic invertebrates, TRVs are often chosen from the low end of a species sensitivity distribution, but do not necessarily represent the most sensitive species of their group, recognizing that the ecological function of benthic invertebrates as a food source does not depend on protecting all species.

For this EcoRA, sediment concentration-based TRVs (mg/kg dry weight) were selected for the benthic community, water concentration-based TRVs (mg/L or µg/L) were selected for aquatic plants, plankton and forage fish, and dose-based TRVs (mg/kg body weight/day) were selected for mammalian and avian wildlife. These TRVs were based on the lowest low-effect threshold concentrations or doses for survival, growth or reproduction.

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 TRV exceedance is considered unacceptable.

Table 4.4: 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	Water Chemistry	Comparison of COPC concentrations to growth, survival and reproduction toxicological reference values (low-effect threshold concentrations).
				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.	Water Chemistry	Comparison of COPC concentrations to growth, survival and reproduction toxicological reference values (low-effect threshold concentrations).
				Radiological Dose	Comparison of estimated doses of COPCs to growth, survival and reproduction benchmark values (low-effect threshold doses) relevant to the assessment endpoint.
Reptiles and Amphibians (Turtles, Frogs)	Population	Maintenance of turtle and frog populations in Frenchman's Bay as sources of food for fish and wildlife.	Viability of turtle and frog populations.	Water Chemistry	Comparison of COPC concentrations to growth, survival and reproduction toxicological reference values (low-effect threshold concentrations).
				Radiological Dose	Comparison of estimated doses of COPCs to growth, survival and reproduction benchmark values (low-effect threshold doses) relevant to the assessment endpoint.

Valued Ecosystem Components	Level of Protection	Protection Goal	Assessment Endpoint	Lines of Evidence	
				Line of Evidence	**Use of Measurement Endpoints for Specific LOEs**
Aquatic Plants (Narrow-leaved Cattail)	Population	Maintenance of aquatic plant populations in Frenchman's Bay as a source of food and cover for wildlife.	Viability of aquatic plant populations.	Water Chemistry	Comparison of COPC concentrations to growth, survival and reproduction toxicological reference values (low-effect threshold concentrations) for aquatic plants.
				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 Lake Ontario, Frenchman's Bayas source of food for fish and wildlife.	Richness, diversity, abundance of benthic invertebrates.	Water Chemistry	Comparison of COPC concentrations to water quality guidelines.
				Sediment Chemistry	Comparison of COPC concentrations to sediment quality guidelines.
				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 and Frenchman's Bay as source of food for predatory wildlife.	Viability of aquatic riparian bird populations	Radiological and Toxicological Doses	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 Frenchman's Bay as source of food for predatory wildlife.	Viability of aquatic riparian mammal populations		

Valued Ecosystem Components	Level of Protection	Protection Goal	Assessment Endpoint	Lines of Evidence	
				Line of Evidence	Use of Measurement Endpoints for Specific LOEs
Terrestrial Invertebrates (Earthworm)	Population	Maintenance of terrestrial invertebrate population at the PN site as a source of food for wildlife.	Viability of terrestrial invertebrate populations	Soil Chemistry	Comparison of COPC concentrations to soil quality guidelines.
				Radiological Dose	Comparison of estimated doses to growth, survival and reproduction benchmark values (low-effect threshold doses) relevant to the assessment endpoint.
Terrestrial Plants (Chokecherry, New England aster, Eastern Hemlock, Red Ash, Sandbar Willow, Pine)	Population	Maintenance of the terrestrial plant population at the PN site.	Viability of terrestrial plant populations	Soil Chemistry	Comparison of COPC concentrations to soil quality guidelines.
				Radiological Dose	Comparison of estimated doses to growth, survival and reproduction benchmark values (low-effect threshold doses) relevant to the assessment endpoint.
Terrestrial Birds (Red-winged Blackbird, Red-tailed Hawk)	Population	Maintenance of the terrestrial bird population at the PN site.	Viability of terrestrial bird populations	Radiological and Toxicological Doses	Comparison of estimated doses of COPCs to growth, survival and reproduction benchmark values (low-effect threshold doses) relevant to the assessment endpoint.
Terrestrial Mammals (Meadow vole, Red Fox, White-tailed Deer)	Population	Maintenance of terrestrial mammal population at the PN site.	Viability of terrestrial mammal populations		

Note:
* For Species at Risk (SAR) identified in Table 4.3, the goal is protection of all individuals, recognizing that each individual's health is important to the population, thus any toxicological reference value exceedance is considered unacceptable.

4.1.3 Selection of Chemical, Radiological, and Other Stressors

The same monitoring data sources previously screened for the HHRA (Section 3.1.2) were screened for the EcoRA using the more conservative of available federal and provincial guidelines and objectives as screening criteria. If there was no such guideline or objective, screening criteria were obtained from the literature, and/or derived using federally and/or provincially accepted methods. For COPCs where these criteria are not available, upper estimates of background concentrations or conservative toxicity benchmarks (e.g., no effects levels) are used as screening criteria. Maximum measured concentrations of parameters in surface water, sediment, soil, and air are compared to the selected screening criteria in order to determine the list of COPCs. Contaminants are also retained as COPCs if no screening criteria are available.

Selected radiological stressors are considered of public interest and therefore are carried forward quantitatively in the EcoRA and do not undergo a formal screening assessment. The relevant radionuclides that are the focus of the quantitative assessment are described in the following subsections.

4.1.3.1 Chemical COPCs in Air

Section 3.1.2.1 describes the atmospheric releases due to the operations at the PN site. As per clause 7.3.4.2.5 in CSA N288.6-12, inhalation exposures to biota are usually minor compared to the soil and food ingestion pathways, and can be ignored for most substances, except for substances that do not partition to soil (CSA, 2012). These substances may include gases such as nitrogen oxides, sulphur dioxide, hydrazine, and morpholine, and for these substances air concentrations dominate the exposure pathway to terrestrial biota. For completeness, all chemicals identified in the ESDM reports (Golder, 2015; Ortech, 2019a, 2019b, 2020, 2021) have been screened against relevant ecological benchmarks (Appendix A, Table A.5). However, only chemicals that do not partition to soil were considered for COPC selection for air.

The EcoRA screening of chemical COPCs in air is shown on Table A.5 (Appendix A). As previously discussed in Section 3.1.2.1, modelled POI concentrations were directly compared to guidelines with the same averaging periods or were adjusted to meet the timeframes of the relevant screening criteria using the formula described in Section 17 of O. Reg. 419/05, where necessary.

Maximum predicted POI concentrations for each of the modelled parameters in the 2016-2020 ESDM reports were compared to screening criteria according to the hierarchy presented on Figure 4.2. The MECP AAQC has been used as the preferred screening level, as AAQCs are developed to be protective of health and the environment (MECP, 2020). Where AAQCs were not available other screening levels such as ESLs from the Texas Commission on Environmental Quality (TCEQ, 2016) were used. ESLs are based on data for health effects, odour and effects on vegetation and can therefore be applied as ecological screening levels. There are no MECP AAQC or TCEQ ESL values for hydrazine. In September 2015, TCEQ derived an interim health-based long-term ESL value for morpholine, and this has been used for screening. For hydrazine, toxicity benchmarks from literature were modified and applied as the screening criteria, as further discussed below.

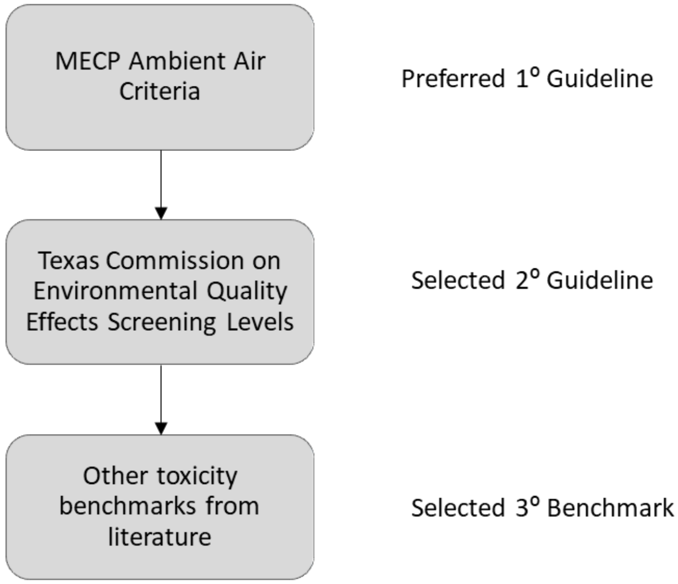


Figure 4.2: Screening Hierarchy for Chemical COPCs in Air for the EcoRA

For NO_x, air concentrations dominate the exposure pathway to terrestrial biota. The main source of NO_x includes combustion emissions from the Auxiliary Heating Steam Facility, Standby Generators, Emergency Power Generators, and minor sources. The highest 1-hour and 24-hour NO_x concentrations at the property line were 394 µg/m^3 and 14.1 µg/m^3, respectively, compared to the AAQC of 400 µg/m^{3}and 200 µg/m^3. These concentrations are below the AAQC and therefore NOx was not carried forward for further assessment.

As shown on Table 2.6, sulphur dioxide is released through combustion the auxiliary steam boiler and diesel-powered air compressors and generators. It was modelled at the highest concentrations in the 2015 ESDM report (Golder, 2015) at a concentration of 333 µg/m^3 at the POI for a 0.5-hour averaging period, adjust to 21.6 µg/m^3 to compare to the annual AAQC of 11 µg/m^3. Although the POI concentrations of SO_2 have decreased since then to concentrations below the AAQC, SO_2 was included as an air COPC for further assessment.

Hydrazine and morpholine are released to the air through atmospheric boiler emissions, as described in Section 3.1.2.1, and do not partition well to soil. The releases due to boiler venting were compared against chronic or sub-chronic toxicity benchmarks.

The screening criterion considered for hydrazine was a Lowest Observable Adverse Effect Level (LOAEL) at 60 µg/m^3 (EC and HC, 2011) converted to a No Observable Adverse Effect Level (NOAEL) by applying a safety factor of 10, resulting in a screening criteria of 6 µg/m^3. This conversion factor has been used to derive the Canadian Water Quality Guidelines for the Protection of Aquatic Life (CCME, 1999), and is the most conservative factor cited in Suter *et al.*

(1993). The maximum annual POI for hydrazine was 0.00039 µg/m^3, well below the screening criterion (Appendix A, Table A-5). Therefore, hydrazine was not carried forward for further assessment as an air COPC.

During the previous ERA (Ecometrix and Golder, 2018), the screening criterion selected for morpholine was the NOAEL for rats in a 13-week study (WHO, 1996) of 90,000 µg/m^3. In 2015, TECQ derived an annual health-based ESL value for morpholine of 40 µg/m^3. This was used to compare against the maximum modelled POI concentrations of morpholine for the current assessment. No exceedances of the TECQ value were noted, and therefore morpholine was not carried forward for further assessment as an air COPC.

Based on the screening presented in Appendix A, Table A.5 for chemicals released to air, sulphur dioxide was carried forward as a COPC for further consideration.

4.1.3.2 Chemical COPCs in Surface Water and Sediment

<u>Surface Water Screening</u>

Surface water screening is based on measurements of chemical COPCs in the CCW discharges from 2019 to 2020, water concentrations in Lake Ontario and Frenchman's Bay collected during the 2014/2015 baseline studies, and ditch samples from 2010-2011 collected as part of bi-annual surface water sampling that was conducted at the East Landfill. Sediment screening is based on chemical concentrations of sediment samples collected from Frenchman's Bay during the 2014/2015 baseline studies.

Surface water COPCs were screened against the screening criteria selected following the process illustrated in Figure 4.3.

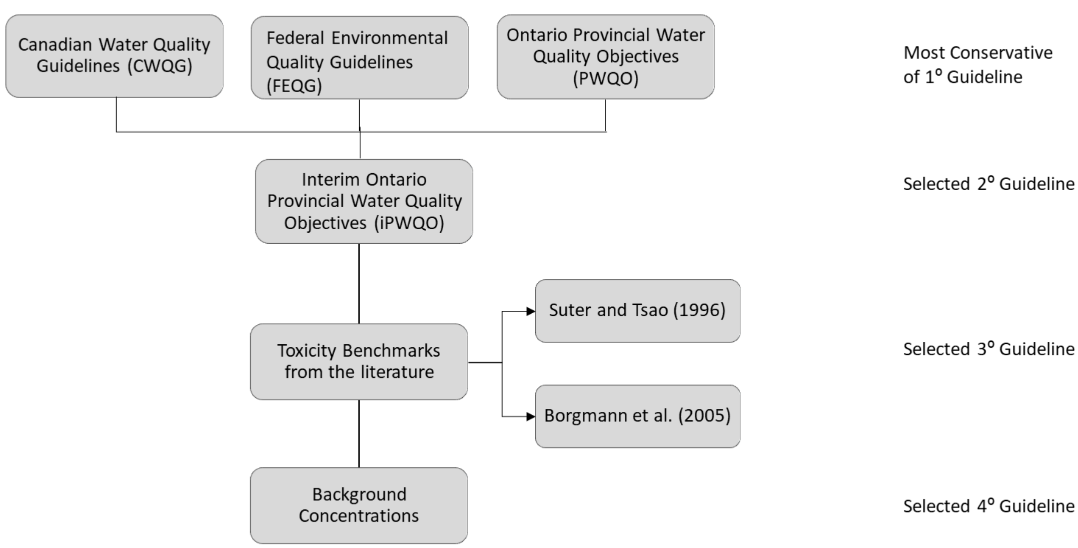


Figure 4.3: Selection of Screening Criteria for Chemical COPCs in Surface Water

The most restrictive federal or provincial guideline for surface water quality, including the CCME water quality guidelines for the protection of freshwater aquatic life (CWQG), the federal environmental quality guidelines (FEQG) and the provincial water quality objectives (PWQO) were selected as the screening criteria for most surface water COPCs. A hardness of 100 mg/L, pH of 8.0, and total organic carbon (TOC) concentration of 0.5 mg/L was assumed to derive parameter-dependent screening guidelines for lake water. Hardness and pH values were selected as a central value representing background and lake water samples. There are no TOC measurements for lake water, and therefore a conservative value was selected; lower TOC values result in more stringent guidelines.

The interim PWQO (iPWQO) were selected as a secondary guideline. The iPWQO were developed for emergency purposes based on readily available information and were not peer-reviewed.

As recommended by Clause 7.2.5.3.2 in CSA N288.6-12, screening criteria should represent no-effect levels. Toxicity based water quality benchmark values were selected from the literature (Borgmann et al., 2005; Suter and Tsao, 1996) for COPCs which do not have a value from the federal or provincial guidelines. The toxicity benchmark values selected for screening are chronic low-effect threshold concentrations for sensitive test species, modified by a safety factor for conversion to a no effect level. In Borgmann et al (2005), values measured from tap water were used over soft water, since the former more closely represents alkalinity conditions in Lake Ontario. Chemicals with maximum concentrations exceeding the selected screening criteria were carried forward as chemical COPCs in the EcoRA. In cases where no toxicity benchmarks were available from selected literature, the maximum concentrations were compared to mean background values collected from Cobourg (LWC-1). These background values are in general agreement with the 95th percentile of Lake Ontario background values from the Drinking Water Surveillance Program (DWSP) (MOECC, 2013a) previously used in the Pickering ERA (EcoMetrix, 2014).

Concentrations of parameters in lake water samples that exceeded background by less than 20% were not identified as exceedances. Differences of less than 20% are typically not statistically discernible or measurable in the field or laboratory (Suter II, 1996; Suter II et al., 1995). Toxicity benchmarks were also used if environmental quality guidelines were lacking, and background concentrations were exceeded by more than 20%.

<u>Sediment Screening</u>

Maximum measured concentrations of sediment parameters were compared against the more conservative values of Ontario Provincial Sediment Quality Guidelines (PSQG, (MOE, 2008)), and the CCME Sediment Quality Guidelines for the Protection of Aquatic Life (CSQG, (CCME, 2001)). If regulatory criteria were not available, values from toxicity studies and other literature were used (Jones et al., 1997; Long and Morgan, 1991; Thompson et al., 2005). If there were no reported toxicity values for a certain parameter analyzed in Lake Ontario, the 95th percentile of background concentrations in Lake Ontario sediment (SENES, 2009) were used as the screening criteria for this parameter. The screening hierarchy for sediment is shown on Figure 4.4.

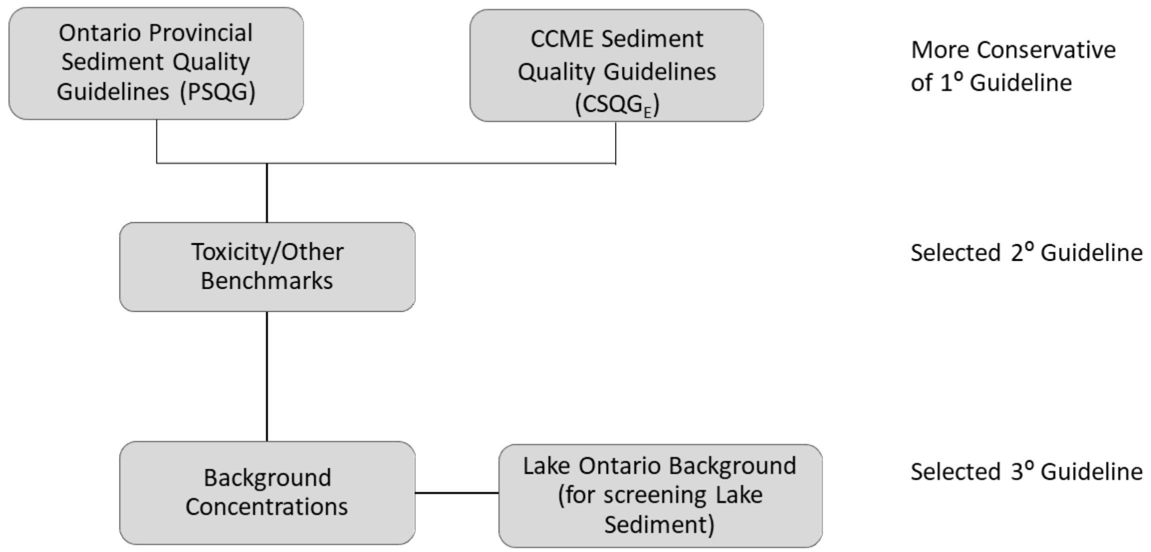


Figure 4.4: Screening Criteria for COPCs in Sediment

4.1.3.2.1 Liquid Effluent

The station effluent from the CCW discharge channel measured from 2016 to 2020 was screened, in order to estimate potential impacts to nearshore water due to effluent loading. The data was previously discussed in Section 3.1.2.2 and the screening based on effluent discharge for the EcoRA is presented in Table A.6.

Each COPC was screened against its screening criterion, which was selected following the process illustrated in Figure 4.3.

Based on the maximum concentrations of contaminants observed in station effluent from 2016 to 2020, hydrazine, morpholine, and total residual chlorine exceeded screening levels and are therefore carried forward for further quantitative assessment.

4.1.3.2.2 Lake Water

The 2014 ERA (Ecometrix, 2014) evaluated lake water data from 2006 and carried forward hydrazine, morpholine, total residual chlorine, copper, and cadmium in the quantitative analysis in the EcoRA.

As discussed in the COPC screening for the HHRA (Section 3.1.2.2), a surface water monitoring program was conducted in the summer of 2015 as part of the updated baseline environmental program in support of the 2017 ERA (Ecometrix and Golder, 2018), to quantify the concentration of COPCs in the PN discharge channels. Since there have not been significant changes to operations at the PN site, the 2015 results were considered to be still applicable for the current assessment. Screening results for the 2015 surface water quality data are presented in Appendix A, Table A.7.

The maximum measured concentrations of copper and morpholine exceed their corresponding surface water quality screening levels. This is consistent with lake water samples from 2006 where elevated levels of both copper and morpholine were observed. In 2006, copper was observed at 0.0025 mg/L at the end of the PN U5-8 discharge channel where the channel enters the lake. The location of LWE-1 from the 2015 sampling campaign is not far from a stormwater discharge pipe (M5-1), which could influence copper concentrations in the lake to a small extent.

For some COPCs (e.g. barium, calcium, magnesium), lake water concentrations exceeded the selected toxicity-based screening value. However, these maximum concentrations only marginally exceeded – between 3 and 7% - the background sample location, LWC1. Since the measured concentrations differed from background by less than 20%, these metals are not carried forward for further quantitative assessment. Silicon was measured at a concentration of 0.66 mg/L, above the LWC-1 background value of 0.26 mg/L. Silicon is a widespread element with low intrinsic toxicity and therefore was not carried forward for further assessment.

Based on the 2014 EMP supplementary study (Ecometrix, 2015) for hydrazine in lake surface water, the maximum observed hydrazine concentration (0.25 µg/L) around PN was below the screening level of 2.6 µg/L (EC, 2013). ECCC has developed a FEQG for hydrazine of 2.6 µg/L for fresh water (EC, 2013). This value represents a predicted no-effect concentration based on an acute toxicity threshold with a safety factor (EC and HC, 2011). Since the maximum observed hydrazine concentration (0.25 µg/L) in lake water was below the screening level of 2.6 µg/L; hydrazine is not carried forward for further quantitative assessment in the EcoRA.

Overall, based on the screening conducted for lake water the following COPCs are carried forward for the EcoRA: morpholine and copper.

4.1.3.2.3 Stormwater

Stormwater runoff from the PN site is collected by the stormwater drainage system and directed through drainage pathways south to Lake Ontario. Surface drainage around PN is comprised of 19 catchments, as discussed in Section 3.1.2.2.3. The point of discharge concentrations were compared against the water quality screening criteria, according to the screening hierarchy presented on Figure 4.3, and criteria protective of ecological endpoints. None of the measured contaminants exceeded the selected screening levels (see Appendix A, Tables A.8a to Table A.8d). Therefore, stormwater is not discussed further in this ERA.

4.1.3.2.4 Surface Water and Sediment at Frenchman's Bay

As part of the updated baseline environmental program, surface water and sediment data were collected in the summer of 2015 from Frenchman's Bay. Frenchman's Bay, a provincially significant wetland, is designated an Environmentally Sensitive Area by the TRCA, and is an Aquatic Biology Core Area. Frenchman's Bay is a habitat for wetland vegetation, mainly cattails, benthic invertebrates, fish, and wildlife. The wetland is located in the northern section of the bay. The 2014 ERA (Ecometrix, 2014) assessed biota at the mouth of the bay where sediment data were collected, and where waterborne emissions from PN have the greatest impact – this is a conservative assumption. One of the main objectives of the Frenchman's Bay surface water and sediment sampling program was to address recommendations in the 2014 ERA to sample sediment and water in the northern section of Frenchman's Bay to reduce uncertainty in the ERA, and to provide additional data for the southern section of the bay.

Surface water and sediment samples were collected in July 2015 from two general areas in Frenchman's Bay, the north end and the south end. In each area of Frenchman's Bay, 10 sediment samples and 3 surface water samples were collected (see Table 4.5, Figure 4.5 and Figure 4.6). Water samples were analyzed for alkalinity, ammonia (total and un-ionized), biochemical oxygen demand, chemical oxygen demand, hardness, pH, conductivity, temperature, total suspended solids, total residual chlorine (in-situ), petroleum hydrocarbons (PHC F1 to F4), morpholine, metals, total organic carbon, and radionuclides. Sediment samples were analyzed for particle size, total organic carbon, metals, and radionuclides. Results for radionuclides for surface water and sediment are discussed in Sections 4.1.3.6 and 4.1.3.8, respectively.

Table 4.5: Frenchman's Bay 2015 Sampling Locations and Descriptions

Location	Sample ID	UTM Easting	UTM Northing	Sample Depth (m)	Depth to Bottom (m)
North end of Frenchman's Bay	Location 1	653410	4853825	0.3 (water) 0-0.05 (sed)	0.59
	Location 2	653379	4853766	0.3 (water) 0-0.05 (sed)	1.2
	Location 3	653273	4853843	0.3 (water) 0-0.05 (sed)	1.6
	F-4	652982	4853934	0.35 (sed)	0.35
	FB-5	653128	4853686	0-0.05 (sed)	1.1
	FB-6	653273	4853649	0-0.05 (sed)	1.5
	FB-7	653381	4853637	0-0.05 (sed)	1.4
	FB-8	653490	4853646	0-0.05 (sed)	1.3
	FB-9	653342	4853903	0-0.05 (sed)	1.5
	FB-10	653138	4853839	0-0.05 (sed)	1
South end of Frenchman's Bay	PN-1-1	653866	4853078	0-0.05 (sed)	2.3
	PN-2-1	653748	4853189	0-0.05 (sed)	2.1
	PN-3-1	653799	4853037	0-0.05 (sed)	2.4
	PN-4-1	653642	4853073	0-0.05 (sed)	2.3
	PN-5-1	653600	4852957	1 (water) 0-0.05 (sed)	2
	PN-6-1	653918	4853230	0-0.05 (sed)	1.4
	PN-7-1	653981	4853078	0-0.05 (sed)	2.1
	PN-8-1	653829	4852992	0-0.05 (sed)	2
	PN-9-1	654051	4852958	1 (water) 0-0.05 (sed)	2.5
	PN-10-1	653927 (water) 653984 (sed)	4852961 (water) 4852938 (sed)	1 (water) 0-0.05 (sed)	1.9

Water Results

Frenchman's Bay water concentrations were screened according to the screening hierarchy shown in Figure 4.3. Where no guideline existed, mean background values from Cobourg (LWC-1 from lake surface water sampling program) were used as screening levels (there were not enough data points for 95th percentile evaluation). These background values are in general agreement with the 95th percentile of Lake Ontario background values previously used in the 2014 ERA (Ecometrix, 2014).

The maximum concentrations of total aluminum and iron at Frenchman's Bay exceeded their respective CCME water quality guidelines and will be retained as COPCs for the EcoRA. In the 2017 ERA (Ecometrix and Golder, 2018), copper was also identified as a COPC. Although the data set has not changed, the maximum concentration of copper does not exceed the hardness-dependent guideline for copper, as shown in Appendix A, Table A.9. Therefore, it has been excluded for further assessment. It is noted that no risks to ecological receptors were identified for copper in Frenchman's Bay in the 2017 ERA (Ecometrix and Golder, 2018).

The field pH in one water sample collected from the south end of Frenchman's Bay PN-5-1 marginally exceeded (8.56 at 1 m depth) the upper end of the pH range (6.5-8.5).

For potassium and sodium no water quality guidelines existed and background concentrations were exceeded by more than 20%; therefore, toxicity benchmarks from Suter and Tsao (1996) were used. Lowest chronic values (LCVs) for potassium and sodium were converted to No Observed Effect Concentrations (NOECs) by incorporating a safety factor of 10. The maximum water concentration for potassium was below its toxicity benchmark. The maximum sodium concentration observed at Frenchman's Bay exceeded its toxicity benchmark.

Based on the screening presented in Table A.9 (Appendix A), total aluminum, iron, and sodium exceed water quality screening levels and are carried forward for further quantitative assessment in the EcoRA. The contribution from PN to water concentrations observed in Frenchman's Bay is discussed in the exposure assessment and in Appendix E.

Sediment Results

Screening of sediment COPCs for the EcoRA was conducted following the screening hierarchy presented on Figure 4.4. Based on the results of the screening presented in Table A.10 (Appendix A), for surficial sediment samples collected in July 2015 from the north and south ends of Frenchman's Bay, the following metals exceeded sediment quality screening levels: boron, cadmium, chromium, copper, iron, lead, manganese, nickel, phosphorus, thallium, tin, and zinc.

Aluminum was identified as a COPC in the 2017 ERA based on background concentrations (Ecometrix and Golder, 2018), but it was found to be less than the probable effect concentration was used for the current screening from Jones et al (Jones et al., 1997).

The maximum concentration for bismuth exceeded the background concentration; however, bismuth has not been detected in either data set, as the screening and maximum values were determined from detection limits. The potential for impact to ecological receptors due to aluminum and bismuth is considered to be low, but they have been kept in EcoRA for consistency with the 2017 ERA assessment.

The maximum concentration of calcium in lake sediment also exceeded the selected screening criterion, which was derived from the background calcium concentration in Lake Ontario sediment. Calcium is a natural component of sediment and not a toxicant to ecological life. Therefore, it was not carried forward as a chemical COPC for further assessment in the EcoRA.

Total organic carbon also exceeds the MOECC lowest effect level (LEL), and is therefore carried forward for further quantitative assessment. Exceedances were expected as Frenchman’s Bay, which is greatly influenced by urban runoff. The sediment results are comparable with the (TRCA, 2009b) and the (OPG, 2002b) sediment results from Frenchman’s Bay.

The contribution from PN to sediment concentrations observed in Frenchman’s Bay is discussed in the exposure assessment and in Appendix E.

Figure 4.5: North Frenchman's Bay 2015 Sampling Locations

Figure 4.6: South Frenchman's Bay 2015 Sampling Locations

4.1.3.2.5 East Landfill Surface Water

Bi-annual surface water sampling was conducted at the East Landfill every two years from 1996 to 2013 as part of PN's East Landfill Perpetual Care Program. The program involved a visual inspection, surface water and groundwater sampling from a number of locations including seepage and ditch points as shown on Figure 4.7. All results were reported to the MOECC. The analytical parameters monitored in this surface water program included: alkalinity, biochemical oxygen demand (5-day), calcium, copper, dissolved organic carbon, hardness, pH, phenols, sulphate, total suspended solids, total phosphorous and zinc. For some years a wider list of metals including mercury was included in the program. As of 2013, OPG has completed its commitment to monitoring surface water at the East Landfill as part of its Perpetual Care Program.

For the purpose of this EcoRA, the 2010 and 2012 sample concentrations were compared against the lowest of the PWQO, CEQG for protection of freshwater life or FEQG water quality guidelines as a primary guideline value, and the interim PWQO as a secondary guideline value, where available, consistent with the screening hierarchy described in Figure 4.3. Where there is no PWQO, CEQG for protection of freshwater life, or FEQG water quality guideline, the CEQG for agriculture – livestock was considered for screening of calcium concentrations. The CEQG – agriculture guidelines are developed to be protective of possible harm to livestock as a result of livestock water use. This screening value was identified for the east landfill surface water only, given that these substances are of minimal concern with presumably small flows to the lake; and any exposure by ecological receptors would occur through a similar pathway as livestock water (i.e. water ingestion). The screening value for sulphate was based on BC MOE as discussed further below.

Ditch 4 and Ditch 6 are the final surface water discharge points from the east landfill into Lake Ontario, with the majority of the effluent coming from Ditch 6. Ditches 1, 2A, 3, and 5 are located upgradient of the discharge points for Ditch 4 and Ditch 6. In 2010 and 2012, Ditch 4 was not sampled, due to lack of water, accessibility, and safety concerns.

Trigger levels developed by OPG, in consultation with the MOECC have been established for copper (0.15 mg/L) and zinc (0.9 mg/L) at the sampling locations for Ditch 4 and Ditch 6 (OPG, 2011c). These levels are 30 times the PWQO. Data from 2010 and 2012 indicate no exceedances of trigger levels and no exceedances of water quality guidelines for copper and zinc.

Based on data from Ditch 6 from 2010 to 2012, phosphorous was the only COPC that exceeded screening levels. Although observed phosphorus concentrations in Ditch 6 in 2010 and 2012 exceed the provincial guideline for nuisance algal growth, phosphorus in its chemically combined forms is not toxic to aquatic life (MOEE, 1979). These combined forms, such as phosphate, are the expected forms on the site, and in most surface waters. Both MECP (MOEE, 1994) and CCME (CCME, 2004) water quality guidelines for total phosphorus focus on its potential effects in enhancing algal growth. The implications of exceeding the phosphorus guideline in Ditch 6 are possible enhancement of algal growth and associated aquatic community effects, which are not uncommon in drainage ditches.

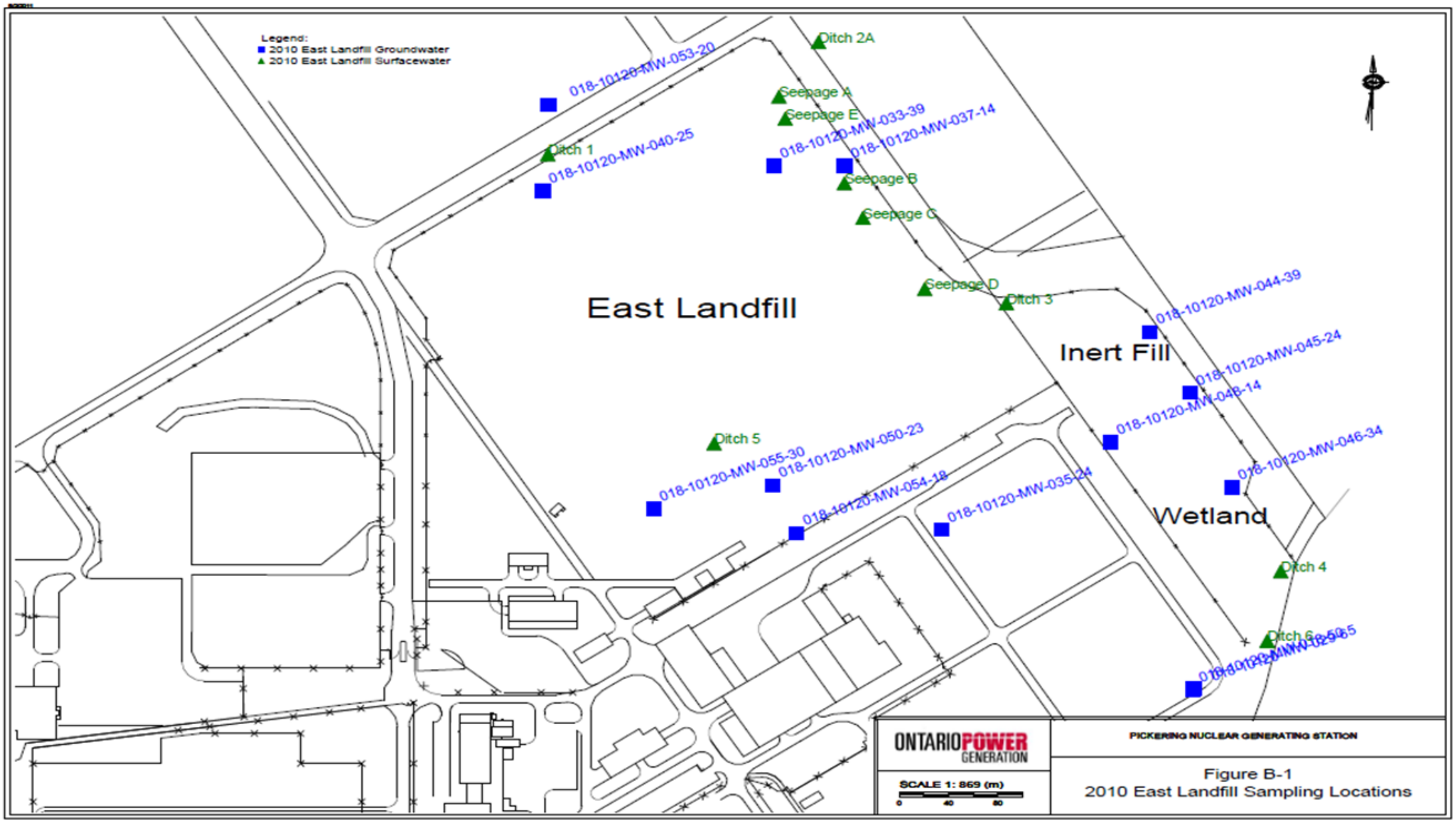
Assessment of Sulphate in the 2017 ERA

During the previous ERA (Ecometrix and Golder, 2018), sulphate was screened in as a COPC using the BC MOE short-term maximum water quality guideline from 2000 for the protection of freshwater aquatic life (100 mg/L). The 100 mg/L value was based on an acute toxicity test for *H. azteca* of 205 mg/L (96-hour LC_{50}), and incorporates a safety factor of 2.

The previous ERA also looked at the April 2013 update to the sulphate water quality guideline published by BC MOE based on a number of toxicity studies linking sulphate toxicity to water hardness, as discussed below.

Elphick et al. (Elphick et al., 2011) performed chronic toxicity tests on nine test organisms over four levels of water hardness (40, 80, 160, and 320 mg/L). For most test organisms, Elphick et al. (2011) observed a decrease in toxicity to test organisms as hardness increased. However, at a hardness of 320 mg/L, *C. dubia* showed increased sensitivity when compared to the test at 160 mg/L. Elphick et al. concluded that at higher hardness levels (greater than 250 mg/L), osmotic stress could be related to total dissolved solids and not elevated sulphate concentrations.

The highest hardness level observed at the East Landfill was 752 mg/L in 2010 from Ditch 6, with a sulphate concentration of 328 mg/L. Although there is uncertainty in the sulphate benchmark at hardness levels above 250 mg/L, the observed sulphate concentration in Ditch 6 is well below the LC_{20} for trout of 857 mg/L at a hardness of 250 mg/L (BC MOE, 2013) as well as the LC_{25} for *C. dubia* of 425 mg/L at a hardness of 320 mg/L (Elphick et al., 2011). The maximum sulphate in Ditch 6 is below these effect levels as well as below the sulphate guideline at the maximum hardness. Based on these observations, the 2017 ERA concluded that sulphate levels in Ditch 6 are not likely of concern.



Source: (OPG, 2011c)

Figure 4.7: Surface Water Sampling Points for the East Landfill Perpetual Care Program

4.1.3.3 Chemical COPCs in Soil

A site-wide soil monitoring program to characterize soil quality at the PN site was conducted in 1999 by CH2M Gore & Storrie Ltd. and was summarized in the Geology Hydrogeology and Seismicity TSD (Golder, 2007b). Since the original 1999 soil characterization study was completed, the MECP has updated O.Reg 153/04 and issued new soil quality standards (MECP, 2011). In the 2014 ERA (Ecometrix, 2014), soil samples from the site-wide soil monitoring program taken from a depth of 0 to 1.5 m (approximately 5 feet) were compared against updated screening criteria. This depth is appropriate for the terrestrial receptors assessed in the EcoRA. Based on the screening conducted, the 2014 ERA carried arsenic, cadmium, copper, lead, strontium, thallium, and zinc forward for further quantitative analysis in the EcoRA. Based on the results of the 2014 ERA further investigation of metals in soil was recommended in areas where benchmarks for soil invertebrates and plants were exceeded, based on 1999-2000 soil data. Areas on the PN site that were recommended in the 2014 ERA for further investigation included:

- the eastern portion of the PN site;
- north of the intake channel, just south of the Old Water Treatment Plant;
- south west of the East Landfill;
- Parking Area A at Montgomery Road; and
- the area near PN U1 and U2.

A site inspection was performed on May 20, 2015 to assess habitat on the PN site, specifically in the areas listed above, to inform the baseline sampling program. Based on the site inspection, areas without vegetation or organic soil cover were removed from the soil program. These areas were removed as they do not provide a suitable habitat for receptors. Based on the assessment of potential habitat, the area north of the intake channel and the area near PN U1 and U2 were removed from the soil monitoring program conducted in October 2015.

The final eight soil sampling locations are identified in Table 4.6 and Figure 4.9 and focus on areas of known soil impact identified in previous ERAs, environmental site assessments, and a site inspection on May 20, 2015. Surface soil samples were collected and analyzed for polycyclic aromatic hydrocarbons, volatile organic compounds, petroleum hydrocarbons F1 to F4, metals and inorganics, glycol, tritium, gamma emitters (i.e., cesium-137, cesium-134, cobalt-60) and carbon-14.

The focus on surface soils (0 to 20 cm) is appropriate for assessment of baseline ecological risk. In general, valued ecosystem components ingesting soils would only access shallow/surface soils; a shallow root zone is appropriate for herbaceous plants, and soil invertebrates are primarily active in the shallow humus layer. The depth of 0.2 m is considered conservative given that most sources of impact are at surface.

Table 4.6: 2015 Soil Sampling Locations and Descriptions

Location ID	Location Description	UTM Easting	UTM Northing
GMS-26	West of Parking Lot E	655704	4853082
GMS-28	Eastern portion of the site	656019	4852552
GMS-31	Eastern portion of the site	656290	4852486
GMS-38	Parking Area A at Montgomery Rd	655445	4852996
Site 7 SS4	East Site Carpenter Shop	656073	4852560
Site 14 SS3	East Site – ditch north of the east site warehouse	656256	4852860
Site 14 SS5	East Site – ditch north of the east site warehouse	656124	4852875
Site 14 SS6	East Site – pipe fabrication shop drainage ditch	656134	4852853

The maximum concentrations identified from the 2015 soil sampling program were compared to screening criteria following the process illustrated in Figure 4.8. The maximum measured concentrations of soil COPCs were compared against the MECP component values protective of ecological health. The applicable component values include the Plants and Soil Organisms (P&SO) component value, and the Mammals and Birds (M&B) component value. The component values for industrial/commercial land use were selected, which is considered to be appropriate given the highly developed nature of the PN site.

The CCME soil quality guidelines (SQG) were also considered, and the more conservative of the MECP P&SO and M&B component values and the CCME SQGs were selected as screening guidelines. Interim SQGs were also considered, if MECP component values and SQGs were not available.

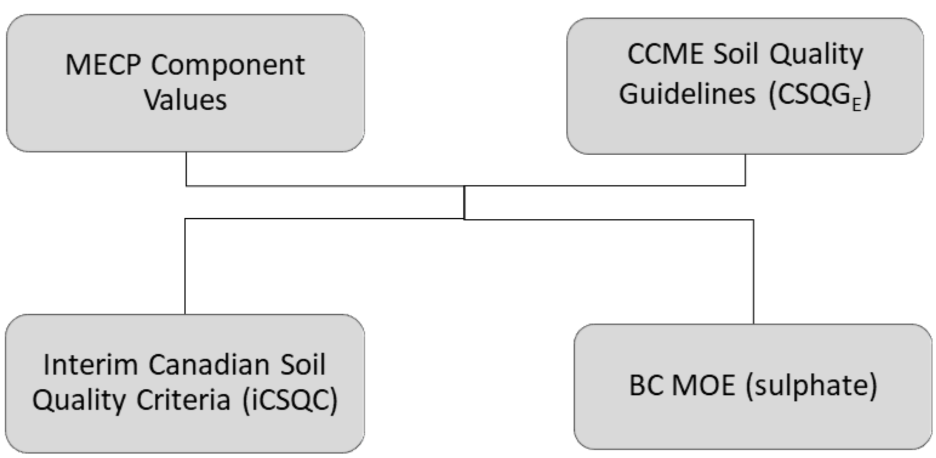


Figure 4.8: Selection of Screening Criteria for Chemical COPCs in Soil

The maximum soil concentration for petroleum hydrocarbon (PHC) F4 (at Site 14-SS5) exceeds the MECP P&SO component value of 3,300 µg/g. PHCs in soil were assessed in a previous Phase II environmental site assessment for the same locations at Site 14 (drainage ditches) (CH2M Hill, 2007). The Phase II environmental site assessment showed an exceedance of the Table 3 standard for F3 at location Site 14-SS6, but petroleum hydrocarbons were below standards for all other locations at Site 14. The elevated PHC F3 concentration identified by CH2M Hill (2007) was not observed at the recently sampled location, and the prior exceedance might be localized. The elevated PHC F4 concentration might be related to minor historical spills and impacted surface water runoff discharging into the ditches.

Although no appropriate screening levels exist for total glycols or diethylene glycol, these parameters have not been carried forward for further quantitative assessment. All soil concentrations for diethylene glycol, ethylene glycol, and propylene glycol are below their respective detection limits; ethylene glycol and propylene glycol are below their respective screening levels.

Cadmium, strontium, and thallium were assessed in the 2014 ERA, but did not exceed screening levels based on 2015 site soil data. The 2014 ERA concluded that the maximum cadmium concentration marginally exceeded the terrestrial plant benchmark south west of the East Landfill. Limited toxicity data were available for thallium and strontium. Where toxicity benchmarks were available, strontium soil concentrations were below these benchmarks. Although thallium concentrations did exceed toxicity benchmarks, the 2014 ERA, concluded that based on the limited extent of the elevated thallium concentrations in soil (eastern portion of the PN site, and south west of the East Landfill), detrimental effects on terrestrial plant communities at the PN site are not expected. Based on the updated 2015 site soil data from comparable locations, cadmium, strontium, and thallium are not carried forward in the EcoRA.

Based on the screening presented in Table A.12 (Appendix A), for surficial soil samples collected in October 2015 from eight locations around the PN site, the following soil COPCs are carried forward for further quantitative assessment in the EcoRA: arsenic, copper, lead, zinc, petroleum hydrocarbon F4, and cyanide. Exceedances of soil screening levels are generally limited to soil samples collected from the eastern portion of the PN site (Site 14 and GMS-28).

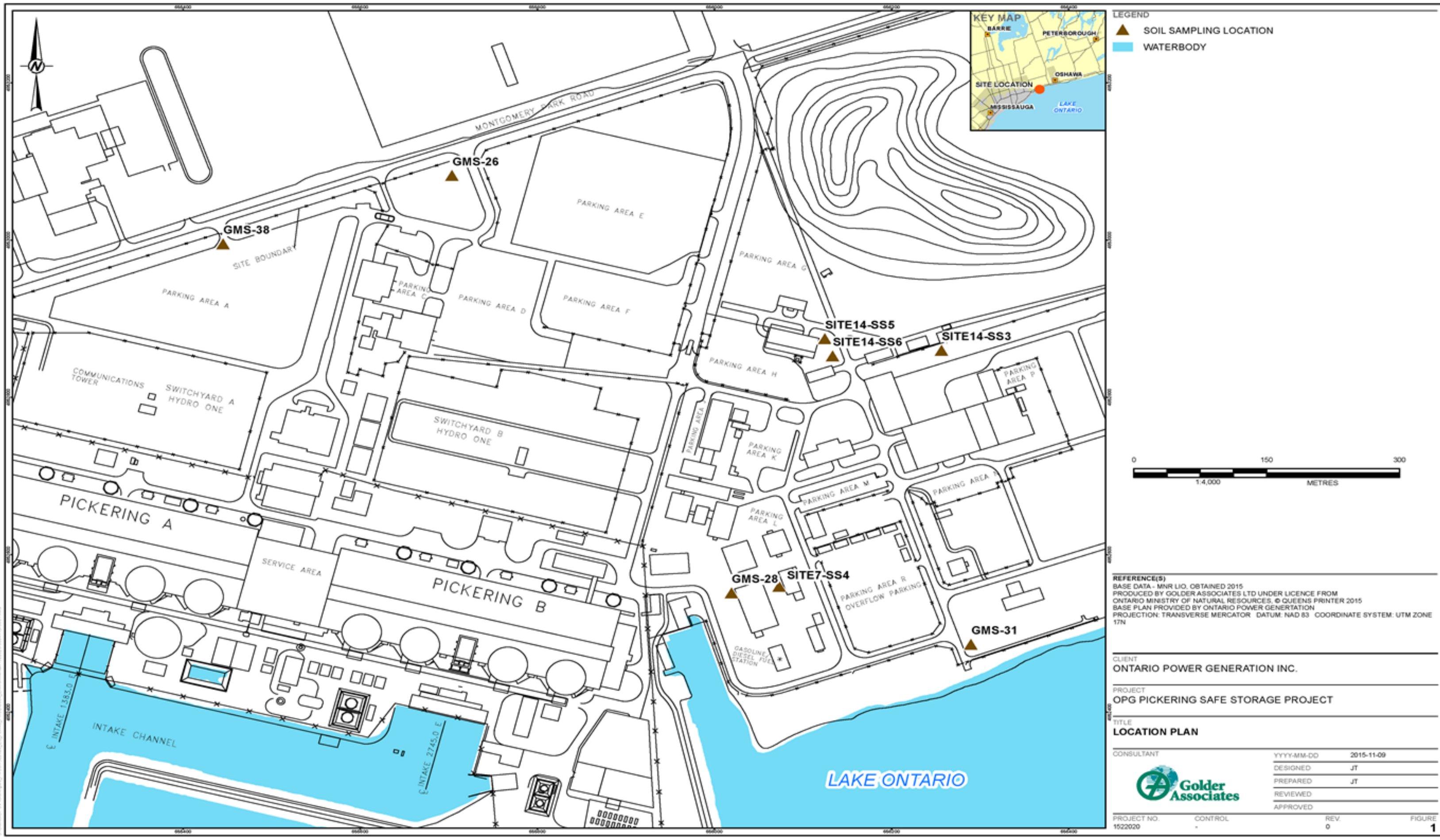


Figure 4.9: 2015 Soil Sampling Locations

4.1.3.4 Chemical COPCs in Groundwater

As discussed in Section 3.1.2.4, non-radiological COPCs in groundwater at the PN Site that are being monitored under the N288.7-compliant GWPP include BTEX, PHCs and dissolved iron. Tritium in groundwater is addressed in Section 4.1.3.10. Results from groundwater monitoring conducted from 2013 to 2020 (OPG, 2013c, 2015, 2016c, 2017c, 2018e, 2019b, 2020e, 2021e) are consistent with the previous assessment.

Although COPCs have been identified through the screening assessment in the CSM supporting the GWPP (Ecometrix, 2020b, 2020a), these COPCs are not being carried forward in the EcoRA. The reasons for this include:

- BTEX and PHC compounds in association with SSCs on site have either not been detected or are non-detect in the plume fringe wells closest to the surface water bodies (intake channel or Lake Ontario) (Section 3.1.2.4);
- Most on-site ecological receptors are not likely exposed to groundwater, since the depth to groundwater on-site is at least 2 metres (Ecometrix, 2020a).
- The direction of groundwater flow at the site is towards Lake Ontario (where not influenced/collected by site infrastructure). As such, there is no exposure pathway from groundwater at PN to offsite terrestrial biota; and
- The ecological receptors identified to be most likely exposed to COPCs migrating with groundwater reside in zones of groundwater discharge to Lake Ontario (Ecometrix, 2020b). These receptors include aquatic invertebrates, bottom-feeding and pelagic fish and riparian birds. These COPCs have been monitored as part of the baseline lake water monitoring program and were screened for the EcoRA, as described previously in Section 4.1.3.2.2. The screening of lake water concentrations (shown in Table A.7 of Appendix A) indicates that concentrations of dissolved iron, BTEX and PHCs in lake water are below screening guidelines protective of ecological health.

4.1.3.5 Radiological COPCs in Air

A summary of airborne radiological emissions from PN is presented in Section 3.1.2.5 of the HHRA. The airborne effluent release groups that are used for DRL calculation and public dose calculation are:

- Tritium oxide as water vapour (HTO);
- Noble gas mixtures (noble gases);
- Radioiodine mixed fission products (mfp);
- Carbon-14 as $^{14}CO_2$ (^{14}C);
- Mixed beta-gamma emitting radionuclides (Particulate); and
- Mixed alpha-emitting radionuclides (Gross alpha).

Air immersion and inhalation pathways for ecological receptors are considered to be minor compared to the ingestion pathway, and were ignored for radionuclides, with the exception of noble gases, which are non-reactive and do not enter the food chain (CSA, 2012). Therefore, the screening for radionuclides in the air pathway focuses on noble gases only.

Ar-41 is the predominant radionuclide measured in noble gas around the Pickering site. The number of operating days of PN U1-4 is related to emissions of Ar-41. Since 2003, an increasing trend of Ar-41 emissions has been observed and is the result of PN U4 returning to service, and PN U1 returning to service in 2005. In 2011, repairs were performed to reduce air ingress via PN U4 calandria vault dryers, reducing Ar-41 levels at the site boundary, compared to 2010 (OPG, 2011d).

Ar-41 emissions are evaluated for human receptors through the annual EMP reports and is carried forward as a COPC for the EcoRA. The dose to non-human biota from exposure to noble gases (predominantly Ar-41) is presented in the Exposure Assessment.

4.1.3.5.1 Pickering Waste Management Facility

As discussed in Section 3.1.2.5, the gamma fields outside the DSC storage buildings at the PWMF are due primarily to contributions from direct gamma radiation and secondarily from gamma skyshine. The neutron dose rate is negligible compared to gamma dose rates. As shown in Table 3.5, the maximum dose rate from the PWMF at full capacity could range from 7.23E-04 to 1.04E-03 µSv/h at the PN property boundary locations (OPG, 2018a). Assuming that this is a whole body effective dose, the tissue absorbed dose at body surface may be slightly higher, but the whole body tissue absorbed dose for wildlife may be lower.

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/h) is equivalent to the whole body absorbed dose for wildlife (µGy/h). For the EcoRA, it has been assumed that the dose to any ecological VEC within the vicinity of the PWMF (at the closest PN property boundary) could range from 7.23E-04 to 1.04E-03 µGy/h, well below the terrestrial dose benchmark of 100 µGy/h.

In 2017, air kerma rates from the PWMF were measured at five transects near the PN site and two background transects starting at the shoreline and out over Lake Ontario (OPG, 2018i). The location of the transects is shown on Figure 4.10. Measurements collected around the PWMF show that the highest air kerma rate contribution at the closest data point is 2.0E-03 µGy/hr, at a distance of 200m from the facility.

Source: (OPG, 2018i)

Figure 4.10: 2017 Air Kerma Sampling Locations

For ecological receptors residing on the PN site, in the immediate vicinity of the PWMF, the expected dose rates are shown in Table 4.7. Assuming the wildlife whole body absorbed dose is comparable to the human effective dose, the dose rate could be up to 0.5 µGy/h for ecological receptors in close proximity to the PWMF, assuming the PWMF is at full capacity.

The combined dose from the PWMF and other activities at PN to ecological receptors is discussed in the Exposure Assessment.

Table 4.7: Maximum Dose Rates in Close Proximity to PWMF Phase I and Phase II

Site	Location	Dose Rate (µGy/h) at full capacity (OPG, 2018a)
PWMF Phase I	Perimeter fence east of PWMF Phase I	0.24
PWMF Phase II	Perimeter fence (18m from DSC Storage Building 3)	0.29

4.1.3.6 Radiological COPCs in Surface Water

The liquid effluent release groups that are used for DRL calculation and public dose calculation at PN (OPG, 2017i) are:

- Tritium oxide as water (HTO),
- Mixed beta-gamma emitting radionuclides (Gross beta-gamma),
- Carbon-14 as dissolved carbonate/bicarbonate (^{14}C), and
- Mixed alpha emitting radionuclides (Gross alpha).

These release groups were identified as being important for estimating potential impacts on human health partly because they are present in, and measured in, air and water effluents at PN.

Because of their presence and importance in PN effluents, these same release groups were considered for estimating potential impacts on ecological health.

As discussed in Section 3.1.2.5, the limiting radionuclides (i.e., the radionuclide with the highest dose per unit release) for gross beta/gamma in water were used to represent all radionuclides in each grouping. Cesium-134 was chosen to represent gross beta/gamma emissions in water, and provides a conservative estimation of radiological dose (see Appendix C). These radionuclides are generally consistent with those measured in surface water during the 2015 updated baseline environmental program, including tritium, carbon-14, cesium-134, cesium-137, and cobalt-60. These COPCs will be assessed quantitatively for radiological dose to ecological VECs.

Gross alpha radionuclides do not need to be carried forward for the risk assessment. The level of airborne and waterborne gross alpha emissions from OPG nuclear facilities has been considered to be negligible (OPG, 2005b). This position is supported by determination of alpha activity in the heat transport water and estimates of the maximum probable emission levels under normal and abnormal operating conditions. The airborne exhaust systems at PN contain HEPA filters which continuously filter particulate from the airborne effluents, thus capturing the alpha emitting particles, resulting in negligible emissions. A study on monthly gross alpha waterborne emissions was performed to establish an appropriate monitoring methodology (OPG, 2006). Based on 2015 monitoring data, gross alpha waterborne concentrations at PN RLWMS are at MDL and their emissions are at a very small fraction (0.00002%) of the monthly DRL.

4.1.3.7 Radiological COPCs in Stormwater

Stormwater was measured in 2015 and 2016 for radionuclides, as summarized in Tables A.8a to Table A.8d in Appendix A. Stormwater is directed to the PN U1-4 or PN U5-8 discharge channels, or to the lake, where it is rapidly diluted, resulting in low concentrations of radionuclides based on contribution from stormwater. Radionuclides are assessed in the exposure assessment were based on lake water concentrations measured during the 2014/2015 baseline program and 2016-2020 CCW effluent concentrations released from the station.

4.1.3.8 Radiological COPCs in Sediment

As discussed in Section 4.1.3.2.4, sediment data were collected in the summer of 2015 from Frenchman's Bay as part of the updated baseline environmental program. The radionuclides of interest were carbon-14, cobalt-60, cesium-134, and cesium-137. Frenchman's Bay is the closest location to PN that is considered a depositional area.

For two radionuclides (cobalt-60, cesium-134), the majority of sediment samples had concentrations of radionuclides below the detection limits. Cesium-137 and carbon-14 were generally detected and results are comparable with the COG sediment study results (Hart and Peterson, 2013).

4.1.3.9 Radiological COPCs in Soil

The Radiation and Radioactivity TSD (SENES, 2007d) identified cesium-134, cesium-137, cobalt-60, and potassium-40 as relevant COPCs for soil and sediment. However, potassium-40 is environmentally abundant and not associated with station operations. The cesium and cobalt isotopes are included as COPCs in order to address potential concern about deposition of particulate activity. Only cesium-134 and cobalt-60 are specific to reactor operations, and these are typically not detected in EMP monitoring of either soil or sediment around the facility.

As discussed in Section 4.1.3.3, a soil monitoring program was conducted in October 2015 as part of the updated baseline environmental monitoring program, and to address recommendations in the 2014 ERA. With respect to radionuclides in soil, the 2014 ERA recommended further investigation of high tritium in soil concentrations near the reactor buildings to clarify the source and extent of these impacts, considering the calculated risks to soil invertebrates and avian consumers, based on 1999-2000 soil data. The ERA noted that avian consumers are unlikely to experience the highest concentrations observed, because of their wide foraging areas.

An inspection of the PN site was performed on May 20, 2015 to assess habitat in areas of potential sampling including areas within the protected area such as adjacent to the reactor buildings. Based on the inspection, areas without vegetation or organic soil cover were removed from the sampling plan as they do not provide a suitable habitat for receptors. Based on the assessment of potential habitat, the area near PN U1 and U2 was removed from the soil monitoring program conducted in October 2015.

Soil samples were collected from eight locations around the PN site (Table 4.6), and analyzed for tritium, gamma emitters (i.e., cesium-137, cesium-134, cobalt-60), and carbon-14.

4.1.3.10 Radiological COPCs in Groundwater

As discussed in Section 3.1.2.7, tritium in groundwater is monitoring at the PN Site under the N288.7-compliant GWPP. Results from groundwater monitoring conducted from 2011 to 2020 (OPG, 2013c, 2015, 2016c, 2017c, 2018e, 2019b, 2020e, 2021e) are consistent with the previous assessment (Ecometrix, 2012).

Although COPCs (tritium) have been identified through the screening assessment in the CSM supporting the GWPP (Ecometrix, 2020b, 2020a), the lack of ecological exposure pathways for site groundwater indicates that there is no need for inclusion of these pathways in the EcoRA. The ecological receptors that are most likely to be exposed to COPCs migrating with groundwater are those that reside in zones of groundwater discharge in Lake Ontario. These receptors include benthic invertebrates living in or on shoreline sediments, and possibly shoreline vegetation with roots near the water table that may be exposed to groundwater when the water table is high. Most on-site ecological receptors are not likely exposed to groundwater, since the depth to groundwater on-site is at least 2 metres (Ecometrix, 2020a).

The N288.7-compliant GWPP (Ecometrix, 2020b) has developed a groundwater evaluation criterion for tritium that would be protective of ecological receptors at the point of exposure, which is the zone of groundwater discharge in Lake Ontario. A tritium concentration of $1x10^8$ Bq/L was derived to be protective of ecological receptors (Ecometrix, 2020b).

Based on groundwater data from 2016 to 2020, the locations where tritium in groundwater exceeds $1x10^8$ Bq/L were around Units 5 and 6 in 2016 and 2017, and near Unit 1 in 2018 and 2020. Groundwater in the Unit 1 area flows either towards the Turbine Auxiliary Bay foundation drains or the Vacuum Building Ramp Sump. Groundwater from PN U5-8 and the PN U5-8 Irradiated Fuel Bay flows to the Turbine Auxiliary Bay foundation drains, which is a hydraulic sink (Ecometrix, 2020b). Groundwater originating from these sources is monitored and has not exceeded the $1x10^8$ Bq/L criterion. These sources are not discharged directly to Lake Ontario. Additionally, relevant ecological receptors are located in the nearshore zones of Lake Ontario in the groundwater discharge area and are not found on-site.

In addition, due to the direction of groundwater flow at the site, there is no exposure pathway from groundwater to offsite terrestrial biota. Groundwater at the site flows towards Lake Ontario, and the effects on aquatic biota are assessed there. The surface water radionuclide concentrations used in assessing exposures of aquatic biota include the contribution from groundwater captured by station structures (i.e., Turbine Auxiliary Bay foundation drains) and from the groundwater discharged directly to Lake Ontario. Review of the annual groundwater monitoring reports shows that the perimeter wells adjacent to Lake Ontario are well below the screening criterion (OPG, 2017c, 2018e, 2019b, 2020e, 2021e). As such, no groundwater COPCs are carried forward for further quantitative assessment in the EcoRA.

4.1.3.11 Physical Stressors

4.1.3.11.1 Noise

Noise levels due to PN may potentially cause disturbance to wildlife. The Pickering B EA Terrestrial Environment TSD (Golder, 2007d) concluded that, although some wildlife may be forced to leave their habitat due to noise levels, most wildlife in the area are likely accustomed to noise levels associated with an urban environment.

As part of the updated baseline environmental program, a noise monitoring program was carried out to monitor existing noise levels, as discussed in Section 3.1.2.8. The noise monitoring program included collecting existing noise levels for environmental noise for human and ecological receptors. The environmental noise results for human receptors are presented in Section 3.1.2.8.

Noise monitoring locations for Environmental Noise (ecological receptors) locations are shown on Figure 4.11 and Table 4.8. The long-term unattended and short-term attended noise monitoring locations for the Environmental Noise (ecological receptors) locations, ES-1 to ES-3, and AES-1 to AES-3 were selected using professional judgement in identifying potential wildlife habitats.

Table 4.8: Noise Monitoring Locations and Descriptions

Sampling ID	Description	Receptor Type	Noise Monitoring Duration
ES-1	Parkland	Ecological	Long-term
ES-2	Shoreline (West of PN)	Ecological	Long-term
ES-3	Open Area	Ecological	Long-term
AES-1	Open Area	Ecological	Short-term
AES-2	Open Area	Ecological	Short-term
AES-3	Shoreline (East of PN)	Ecological	Short-term

Environmental noise levels for ecological receptors were assessed for a sensitive time period – 06:00 to 10:00. There are no specific noise level thresholds for ecological receptors within regulatory documents. For the Environmental Noise (ecological receptors) locations, the long-term unattended noise monitoring was carried out between September 18 and September 25, 2015. Approximately 160 hours of data were collected at each noise monitoring location, with 115 hours considered to be valid data. Periods of inclement weather, unsuitable for noise measurements, were identified and excluded from the calculations. Short-term attended measurements were carried-out to supplement the unattended monitoring data.

Un-weighted linear noise levels (dBZ) may be considered more appropriate for evaluating potential effects on ecological receptors than A-weighted (dBA) levels, which are used to describe human responses to noise. The un-weighted noise levels (LZeq) represent the actual acoustic energy in the atmosphere between 20 and 20,000 Hz and can be considered a less biased representation of how ecological receptors may react to noise levels in the environment. However, as various literature references both un-weighted linear and A-weighted sound levels, both were collected during the noise monitoring program for ecological receptors. The results for noise levels collected during the baseline noise monitoring program at long-term unattended monitoring locations are shown in Table 4.9 to Table 4.11. The results for short-term attended monitoring locations are shown in Table 4.12.

Table 4.9: Environmental Noise (ecological receptors) Locations ES-1 Long-term Unattended Noise Monitoring Results

Time Period	L_{Zeq} *(1-h)*			L_{Aeq} *(1-h)*		
	Average (dBZ)	Maximum (dBZ)	Minimum (dBZ)	Average (dBA)	Maximum (dBA)	Minimum (dBA)
Ecological (06:00 – 10:00)	64	66	60	50	53	44
Daytime (07:00 – 19:00)	65	69	60	49	54	44
Evening (19:00 – 23:00)	63	65	61	47	51	42
Night-time (23:00 – 07:00)	66	77	59	46	49	40
24 h	65	77	59	48	54	40

Table 4.10: Environmental Noise (ecological receptors) Location ES-2 Long-term Unattended Noise Monitoring Results

Time Period	L_{Zeq} (1-h)			L_{Aeq} (1-h)		
	Average (dBZ)	Maximum (dBZ)	Minimum (dBZ)	Average (dBA)	Maximum (dBA)	Minimum (dBA)
Ecological (06:00 – 10:00)	65	68	62	57	62	47
Daytime (07:00 – 19:00)	71	79	63	58	67	48
Evening (19:00 – 23:00)	66	73	63	56	62	47
Night-time (23:00 – 07:00)	65	68	62	57	62	47
24 h	69	79	62	57	67	47

Table 4.11: Environmental Noise (ecological receptors) Location ES-3 Long-term Unattended Noise Monitoring Results

Time Period	L_{Zeq} (1-h)			L_{Aeq} (1-h)		
	Average (dBZ)	Maximum (dBZ)	Minimum (dBZ)	Average (dBA)	Maximum (dBA)	Minimum (dBA)
Ecological (06:00 – 10:00)	63	68	60	47	54	43
Daytime (07:00 – 19:00)	69	79	62	52	61	45
Evening (19:00 – 23:00)	64	68	62	49	54	44
Night-time (23:00 – 07:00)	63	68	60	47	54	43
24 h	67	79	60	51	61	43

Table 4.12: Environmental Noise (ecological receptors) Locations –Short-term Attended Noise Monitoring Results

ID	Date/Time	Height above grade (m)	L_{Zeq} (1-h) (dBZ)	L_{Aeq} (1-h) (dBA)
AES-1	2015-09-18 / 15:24 (Daytime)	4.5	67	59
AES-1_2	2015-09-25 / 11:51 (Daytime)	4.5	64	51
AES-2	2015-09-18 / 12:43 (Daytime)	4.5	61	53
AES-2_2	2015-09-25 / 06:57 (Night-time)	1.5	65	49
AES-3	2015-09-18 / 13:29 (Daytime)	4.5	63	53

Similar to the human receptor noise data, noise levels were generally higher in the daytime than the evening and night-time periods at the Environmental Noise (ecological receptors) locations. Also, the noise levels during the ecological time period (06:00 (dawn) to 10:00) tended to be similar to those during the night-time period. It was generally observed on site that the local acoustic background consists of the sounds of road traffic, and residential maintenance and construction (i.e., lawn cutting, deck building). In areas near the shoreline, it was observed that the sounds of wave action dominate the acoustic environment. These sounds are consistent with the urban environment within which PN is located.

Noise levels at PN can potentially cause disturbance to wildlife. The Pickering B EA Terrestrial Environment TSD (Golder, 2007d) concluded that, although some wildlife may be sensitive to high noise levels, most wildlife in the area (onsite and offsite) are likely accustomed to noise levels associated with an urban environment, and have already acclimated to the noise levels in this specific environment as the PN facility has been fully operational for three decades. There is no specific noise level threshold for wildlife within official regulatory documents. Based on the discussion above, exposure of non-human biota to noise levels from PN is not discussed further.

Figure 4.11: Environmental Noise (Ecological Receptors) - Long-term Unattended and Short-term Attended Noise Monitoring Locations

4.1.3.11.2 Thermal Stressors, Entrainment, Impingement

CSA N288.6-12 (CSA, 2012) recommends that thermal stressors and entrainment and impingement should be carried forward for assessment in the EcoRA since they are widely recognized as being of primary concern at nuclear power plants. Thermal effects on fish, and impingement/entrainment will be carried forward as physical stressors of concern, and do not require formal screening.

Under normal operations, the 24-hour temperature difference limit in the current ECA (No. 0590-BEDKHH, issued August 9, 2019) for PN is 11°C between the forebay intake water and the CCW discharge ducts. These limits have not changed from prior ECAs (OPG, 2016d). The station effluent discharge temperature limit is 36°C from July 1 – October 31 and 32°C from November 1 to June 30. However, under special circumstances, namely algal events, and declared Electricity Supply Emergency event days, special ECA limits apply. During algal events, the Station Effluent Discharge Temperature Limit is 37°C and the temperature difference limit is 16°C. The temperature limits for station effluent discharge under different operating conditions are shown in Table 4.13.

Table 4.13: Environmental Compliance Approval Discharge Temperature Limits for Different Operating Conditions

Operating Conditions	Period of Year	Effluent Temperature Limit	Temperature Difference Limit (ΔT)	Allowed Period of Operation	Total Number of Operating Days Limit Allowed
Normal	Jul 1 to Oct 31	36°C	11°C	continuous	N/A
	Nov 1 to Jun 30	32°C	11°C	continuous	N/A
Algae Impact Event	Jul 1 to Dec 31	37°C	16°C	Not to exceed 24 h for any single event	16
Declared Electrical Supply Emergency	Jul 1 to Oct 31	37°C	11°C	Not specified	15

There were twelve algae events experienced at PNGS in 2016 (OPG, 2017j). Large floating algae mats caused issues at the station intake in September 2016, causing shutdown of CCW pumps and derating of operating units. The following year, PNGS acquired an algae harvester in 2017 which enables collection of surface algae and other debris in the Forebay prior to entering the station intake (OPG, 2018k). The algae harvester continued to be used during the months of

July, August and September in subsequent years. There were no algae events reported at PNGS in 2017 (OPG, 2018k) and only one minor event reported in 2018.

In 2019, an Advanced Algae Warning System (AAWS) was developed in a partnership between OPG and Michigan Tech University for use at PNGS (OPG, 2020g). The AAWS is a predictive tool to forecast future algae run events. The AAWS components include satellite imagery, drone surveys, water intake/screenhouse cameras, hydrological and algae forecasting models, and observatory buoys combined into a website accessible to OPG staff. Two minor algae events were experienced in each of 2019 and 2020.

Installation of a pilot air bubble curtain system was completed in July 2021 (OPG, 2020h, 2021h), to address increasing abundance of nuisance algae in the nearshore area of Lake Ontario, affecting PNGS operations and causing issues such as single or multi-unit shutdowns. The system is currently in the pilot phase and subject to it's effectiveness may be used to reduce the volume of incoming nuisance algae suspended in the water column by diverting it around the station intake groynes, outside of the FDS (OPG, 2020h). Previously, OPG has implemented mitigation measures and preventive actions in order to minimize the impact of the algae events. These include the following:

- Design modifications to the FDS consisting of the addition of primary and secondary skirts along the top panel of the main net to fill voids along the top of the net that could occur if the main net (or primary skirt) were pulled beneath the surface. When installed the FDS continues to be maintained on an ongoing basis.
- Installation of a new, more efficient Trash Trough Bar Screen in 2012 designed to filter clumps of algae and reduce algae recirculation into the forebay.
- Optimization of the operability of existing equipment in the screenhouse in 2012 by installing new cyclone separators to filter silt and by replacing travelling screen spray wash nozzles with larger diameter nozzles that are less likely to become plugged by debris.
- Improvements to the preventive maintenance program in 2014 to increase the reliability of the travelling screens.

A number of actions were taken in 2014 for the mitigation of ice events. These included improvement in the Ice Barrier at the mouth of the intake channel to maintain its ability to prevent surface/shore ice from entering the Intake Channel; enhancement of operating procedures to reduce severity of ice events; and dredging in the U1-4 intake channel to increase the cross-sectional area of the channel. During the 2016-2020 period, there were zero ice events in the Forebay (OPG, 2017j, 2018k, 2019f, 2020g, 2021h).

4.1.3.11.3 Bird Strikes and Wildlife Collisions

Wildlife strikes with vehicles and bird/bat strikes on buildings are other physical stressors typically addressed in an ERA. These physical stressors have been previously addressed in the

2007 Pickering B EA (Golder, 2007d). Monitoring of wildlife mortality from vehicle strikes has been performed on the Pickering site as part of the Pickering A Return to Service EA Follow-Up and Monitoring Program (reported in the 2008 Pickering B EA). In 2006, 27 mortalities in 24 observation days were observed, which corresponds to 1.08 individual mortalities per observation day. Prior to Pickering A restart, 23 mortalities were observed in 27 days, which corresponds to 0.9 mortalities per observation day. Mortality rates have been fairly consistent over the years where data were collected. The species most commonly struck include the eastern grey squirrel, eastern cottontail, and European starling. Some species identified as VECs have been struck. None of the species recorded as mortalities are considered species of concern. All of the VECs that have been recorded as mortalities are abundant in the vicinity of PN. Based on this observation, the EA states that no population level effects are expected to result from the loss of a few individuals at the low rate of mortality currently observed (Golder, 2007d).

From 2011 to 2020, approximately 47 bird strikes on buildings were recorded through voluntary reporting in Station Condition Records. However, numbers may be higher since this is through voluntary reporting. Data on bird and bat strikes against station buildings is limited; however, it is assumed that the rate is consistent with the number impinged on the wind turbine located on the shoreline next to Pickering. Since the number of birds and bats impinged on the wind turbine is low (4 birds and 8 bats over 1 calendar year) and there are a large number of birds and bats in the area, the EA states that no population level effects are expected to result from the loss of a few individuals. There are uncertainties associated with the assumed comparability of strike rates between the wind turbine and buildings, but the strike rates for buildings are unlikely to be substantially higher, and the rate for the wind turbine is of little consequence, so a similar finding for building strikes is reasonable. Further, the wind turbine west of PN U1-4 was removed in 2019.

According to the discussion above, wildlife strikes with vehicles, and bird and bat strikes on buildings, do not need to be carried forward for further consideration in the EcoRA.

4.1.3.12 Summary of COPC Selection for the EcoRA

Table 4.14 summarizes the radiological and non-radiological COPCs that are carried forward to the exposure assessment in the EcoRA.

Table 4.14: Summary of COPCs Selected for the Ecological Risk Assessment

Category	Radiological COPC	Non-Radiological COPC
Air	noble gases (represented by argon-41) (PN site)	sulphur dioxide
Surface water	tritium, carbon-14, gross beta-gamma (represented by cobalt-60), cesium-134, cesium-137 (Lake and Frenchman's Bay)	hydrazine, total residual chlorine, morpholine (CCW to Lake); copper (Lake) total aluminum, iron and sodium (Frenchman's Bay)
Groundwater	None	None
Stormwater	None	None
Sediment	carbon-14, cesium-134, cesium-137, cobalt-60 (Frenchman's Bay)	aluminum, bismuth, boron, cadmium, calcium, chromium, copper, iron, lead, manganese, nickel, phosphorous, thorium, tin, zinc, total organic carbon (Frenchman's Bay)
Soil	tritium, carbon-14, cesium-134, cesium-137, cobalt-60 (PN site)	cyanide, arsenic, copper, lead, zinc, and petroleum hydrocarbon F4 (PN site)
Physical Stressor (Noise, Bird Strikes/Wildlife Collisions)	None	
Physical Stressors	impingement/entrainment	
	thermal plume	

4.1.4 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 measured concentrations of COPCs wherever such data exist, and estimating concentrations where measured values are not available.

For fish, frog and aquatic plants, contact with water and contaminant uptake from water via bioaccumulation represents the main exposure pathway. For soil invertebrates and terrestrial plants, the main exposure pathway is through contact with soil and contaminant uptake from soil via bioaccumulation. The dominant exposure pathways for birds, mammals and turtles is 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 latter pathways will be omitted for ecological receptors in this assessment, except for noble gases, as noted in Section 4.1.3.5.

4.1.5 Ecological Conceptual Model

The conceptual model 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. 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. Table 4.15 summarizes the relevant exposure pathways for each type of ecological receptor. The conceptual model for the EcoRA is illustrated on Figure 4.12. 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 in this case. In addition, the figures incorporate 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.

The 2007 EcoRA to support the Pickering B Refurbishment and Continued Operation EA, assessed aquatic biota for non-radiological exposure at the Hydro Marsh. This marsh in the lower reach of Krosno Creek is fed by natural creek drainage and storm water inputs, and drains into the south-east side of Frenchman's Bay. Historically, this location was assessed because there was a pipeline which discharged CCW from PN through a fish farm to the Hydro Marsh. This pipeline was disconnected in 1997, and follow-up field studies have shown there is no accumulation of radionuclides in the marsh, and contaminant accumulation patterns do not correlate with effluent from the PN site (SENES, 2007e). Without the pipeline, it is unlikely that PN has an influence on the water and sediment quality at the Hydro Marsh.

Frenchman's Bay is a provincially significant wetland, is designated an Environmentally Sensitive Area by the TRCA, and is an Aquatic Biology Core Area. Frenchman's Bay is a habitat for wetland vegetation, mainly cattails, benthic invertebrates, fish, and wildlife. Frenchman's Bay is Hydro Marsh's link to Lake Ontario, and water from the lake enters the system when the water level rises in Lake Ontario (Golder, 2007a). Therefore, Frenchman's Bay is potentially impacted by non-radiological and radiological waterborne discharges from PN operations. It provides a habitat for all the VEC species identified in Table 4.14. This includes habitat for the Red-winged Blackbirds that use the wetland as a source of food and nesting habitat, primarily among the cattails (SENES, 2007e). The wetland is located in the northern section of the bay. Sediment and water data are available from both the northern and southern sections of Frenchman's Bay.

Although the Hydro Marsh experiences airborne deposition from atmospheric emissions from PN, tritium in air concentrations from the EMP reports show that the difference in dispersion factors between Hydro Marsh and Frenchman's Bay is minor. In 2016, an EMP supplementary study was conducted to confirm that the effects of airborne deposition in the marsh are minor, through the collection of surface water samples from Hydro Marsh and Frenchman's Bay and evaluation of the measured results for statistically significant difference (OPG, 2017a). The study found that the concentrations in Hydro Marsh are statistically equal to those of Frenchman's Bay

(OPG, 2017a). Therefore, Frenchman's Bay is a suitable location to assess riparian and aquatic receptors, and it is not necessary to consider Hydro Marsh as a separate assessment location.

All the avian receptors to be assessed are migratory, and are likely to reside at the PN site for half of the year. However, for the exposure assessment, their occupancy at the site is assumed to be for the whole year.

Fish are abundant in the discharge channel, which provides a spawning habitat for Smallmouth Bass. There is also very sparse vegetation cover along the discharge channel (Golder, 2007a). Due to the prevalence of fish at the discharge channel, fish are assessed at the outfall.

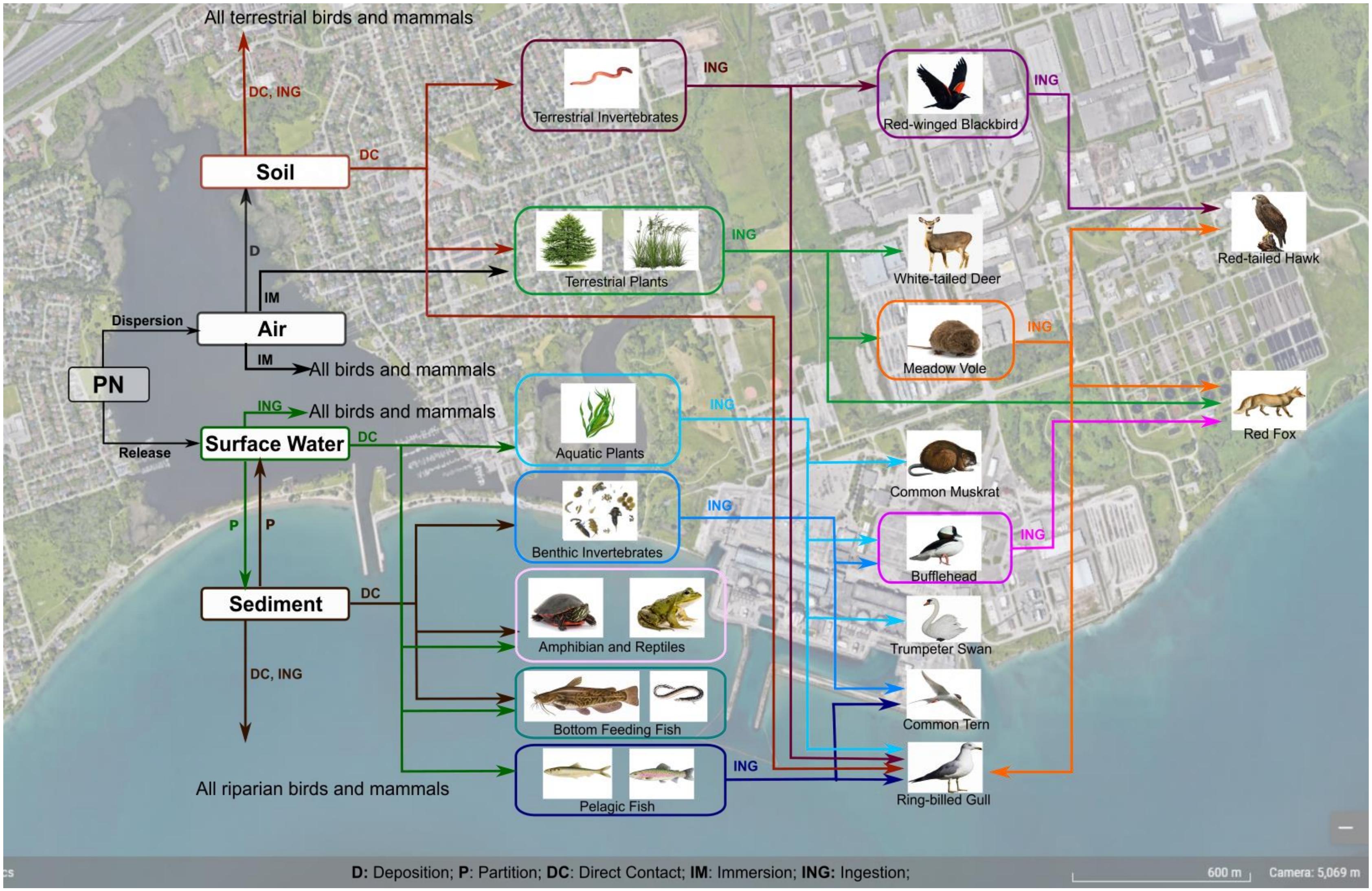


Figure 4.12: Conceptual Model for the Ecological Risk Assessment

Table 4.15: Complete Exposure Pathways for All Selected VEC Species

VEC Category	Location	VEC	Exposure Pathways	Environmental Media
Benthic Fish	Outfall Frenchman's Bay	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	Outfall Frenchman's Bay	Emerald Shiner	Direct Contact*	Water
		Lake Trout	Direct Contact*	Water
		Northern Pike	Direct Contact*	Water
		Smallmouth Bass	Direct Contact*	Water
		Walleye	Direct Contact*	Water
Amphibians and Reptiles	Frenchman's Bay	Midland Painted Turtle	Direct Contact*	Water Sediment
		Northern Leopard Frog	Direct Contact*	Water Sediment
Aquatic Plants	Frenchman's Bay	Narrow-leaved Cattail	Direct Contact*	Water Sediment
Aquatic Invertebrates	Outfall Frenchman's Bay	Benthic Invertebrates	Direct Contact*	Sediment
Riparian Birds	Frenchman's Bay	Bufflehead	Immersion	Air
			Ingestion	Water Sediment Benthic Invertebrate Aquatic Plant
		Common Tern	Immersion	Air
			Ingestion	Water Sediment Benthic Invertebrate Pelagic Fish
		Trumpeter Swan	Immersion	Air
			Ingestion	Water Sediment Aquatic Plant
		Ring Billed Gull	Immersion	Air
			Ingestion	Water Sediment Aquatic Plant (at FB) Pelagic Fish (at FB) Benthic Invertebrate (at FB) Muskrat (at FB)
	Outfall	Ring Billed Gull	Immersion	Air
			Ingestion	Water Sediment Aquatic Plant (at FB) Pelagic Fish (at Outfall) Earthworm (at PN site)

VEC Category	Location	VEC	Exposure Pathways	Environmental Media
				Meadow Vole (at PN site)
Riparian Mammals	Frenchman's Bay	Muskrat	Immersion	Air
			Ingestion	Water Sediment Aquatic Plant
Terrestrial Plants	Pickering Nuclear site	Chokecherry	Immersion	Air
			Direct Contact	Soil
		New England Aster	Immersion	Air
			Direct Contact	Soil
		Eastern Hemlock	Immersion	Air
			Direct Contact	Soil
		Red Ash	Immersion	Air
			Direct Contact	Soil
		Sandbar Willow	Immersion	Air
			Direct Contact	Soil
		Pine/Grass	Immersion	Air
			Direct Contact	Soil
Terrestrial Invertebrates	Pickering Nuclear site	Earthworms	Direct Contact	Soil
Terrestrial Birds	Pickering Nuclear site	Red-winged Blackbird	Immersion	Air
			Ingestion	Insects Soil Water
		Red-tailed Hawk	Immersion	Air
			Ingestion	Red-winged Blackbird Meadow Vole Soil Water
Terrestrial Mammals	Pickering Nuclear site	Red Fox	Immersion	Air
			Ingestion	Soil Terrestrial Vegetation Meadow Vole Red-winged Blackbird Water
		Meadow Vole	Immersion	Air
			Ingestion	Soil Terrestrial Vegetation Water
		White-tailed Deer	Immersion	Air
			Ingestion	Soil Terrestrial Vegetation Water

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

For organism losses by entrainment/impingement, the conceptual model illustrated in CSA N288.6-12 (CSA, 2012) is appropriate. This conceptual model (Figure 4.13) represents the relationship between the individual losses and possible population or community effects. Based on monitoring for a 5-year period from 2016 to 2020, the most impinged site relevant species are Alewife, Round Goby, Three-Spine Stickleback, Gizzard Shad, Emerald Shiner, and Rainbow Smelt. Northern Pike is relevant as well as the species is prevalent in the winter when the Fish Diversion System is not in place. Impingement of species at risk such as American Eel is also relevant. Fish impingement is quantified as biomass. For entrainment, fish eggs and larvae are relevant and are expressed as age-1 equivalents.

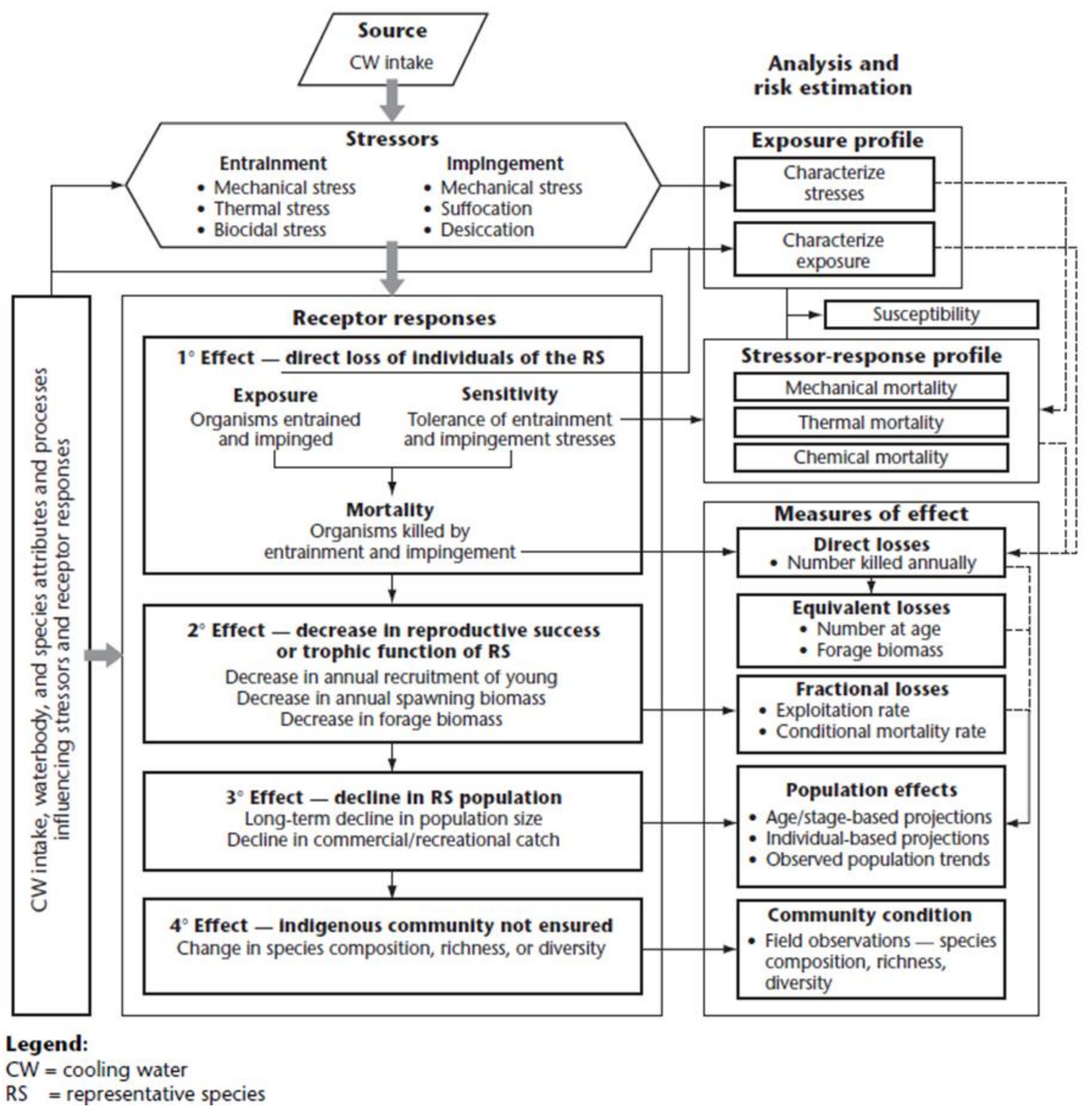


Figure 4.13: Conceptual Model for Relationships between Individual Endpoints and Population/Community Endpoints (CSA, 2012)

4.1.6 Uncertainty in Problem Formulation

The data used in the assessment were concluded to be of adequate quality and quantity to support the objectives of the EcoRA. Maximum measured concentrations were selected for COPC screening; this is considered conservative and is not reflective of typical ecological exposures, with the exception of stationary receptors such as plants; for plants, this selection is realistic. The ecological screening benchmarks for water were generally the lower of applicable provincial and federal aquatic life objectives and guidelines, which is a conservative approach, ensuring that the list of COPCs would be as comprehensive as possible. The COPC screening also considered several media as potential exposure routes, such as air, surface water, soil, ground water, and sediment, and including effluent and stormwater. As such, the COPC screening has resulted in a conservative list of COPCs.

Uncertainties were also inherent in the selected ecological screening benchmarks. Several of the screening benchmarks (e.g., MECP P&SO and M&B component values) are based on Lowest Observed Adverse Effect Levels (LOAELs), and not on No Observed Adverse Effect Levels (NOAELs). Others were conservatively based on background concentrations for lake water or soil. These concentrations are not based on toxicological considerations. Nevertheless, these values represent the best available screening criteria for the parameters in question and are considered to be suitable for screening purposes in the context of a risk assessment.

More generally, the problem formulation has been conservative in its assumptions, to accommodate uncertainties, and to ensure that the subsequent EcoRA does not overlook any issues of potential concern. The conceptual model for ecological health is considered to be complete for the majority of ecological exposures in the vicinity of the PN site. The comprehensive selection of COPCs and receptors is expected to represent all important exposures to contaminants in the vicinity of the PN site.

4.2 Exposure Assessment

4.2.1 Exposure Points

Measured concentrations of COPCs for the various media at the receptor locations listed in Table 4.15 were generally available. The exposure concentrations at the exposure locations are further described in Section 4.2.5. The majority of the exposure point concentrations were obtained from:

- 2015 baseline environmental monitoring program for surface water, sediment, soil;
- OPG Annual EMP reports (years 2016 to 2020); and
- Effluent concentrations (years 2016 to 2020).

4.2.2 Exposure Averaging

4.2.2.1 Exposure Averaging

When multiple measurements and samples were available for a given COPC in a particular medium at an assessed exposure location, the arithmetic mean, as well as maximum concentrations were calculated based on the available data. Birds and mammals are likely to experience something close to average concentrations as they move around the area. However, for less mobile organisms such as plants and invertebrates, both average and upper limit concentrations represent exposures that would be experienced by some organisms on a long-term basis.

4.2.2.2 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)

For COPCs without sediment data, the sediment distribution coefficients (K_d) used in the environmental partitioning calculations are listed in Table 4.16. For COPCs that do not have a sediment K_d in CSA N288.1 or International Atomic Energy Agency (IAEA, 2010), the soil K_d published in IAEA (IAEA, 2010) was used. The soil K_d is multiplied by a factor of 10 to take into account the typically higher water content (water filled porosity) in sediment and greater available particle surface area for adsorption.

Table 4.16: Sediment Distribution Coefficients

COPC	Distribution Coefficient (K_d) (L/kg dw)	Reference
Tritium	0	CSA, 2014; 2020
Carbon-14	50	CSA, 2014; 2020
Cobalt-60	43,000	CSA, 2014; 2020
Cesium-134	9,500	CSA, 2014; 2020
Cesium-137	9,500	CSA, 2014; 2020
Chlorine (TRC)	0	see text below
Copper	2,700	IAEA, 2010 (soil value x 10)
Hydrazine	0	See text below
Morpholine	0	See text below

The environmental partitioning of hydrazine has been modeled and described (EC and HC, 2011). The modeling results show that when hydrazine is released to surface water, it will remain almost entirely in the water (99.9% in water, 0.02% in sediment). Based on these results, the partitioning of hydrazine from water to sediment is negligible as the K_d is 0 L/kg dw. Due to morpholine's solubility in water, when it is released into the environment, it moves with soil moisture and water, and does not sorb to sediment or organic matter (Lewis et al. as cited in (Poupin et al., 1998)). Therefore, the K_d for morpholine for this assessment is 0 L/kg dw. TRC is not expected to be measurable in sediment or soil because it reacts and volatilizes rapidly (ATSDR, 2010).

4.2.3 Exposure and Dose Calculations

Exposure and dose calculations for each COPC were performed for the ecological receptors and receptor locations outlined in the ecological conceptual model (Section 4.1.5)

4.2.3.1 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 version 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 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 terrestrial biota is estimated using a method similar to that for riparian biota, except the external dose component is driven by soil rather than water and sediment. The equations used for terrestrial biota to estimate radiation dose 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 soil) ((µGy/d)/(Bq/kg))
$DC_{ext,ss}$	=	external dose coefficient (on soil surface) (µGy/d)/(Bq/kg))
C_t	=	whole body tissue concentration (Bq/kg fw)
C_s	=	soil concentration (Bq/kg dw)
OF_s	=	occupancy factor in soil (unitless)
OF_{ss}	=	occupancy factor at soil surface (unitless)

For riparian biota, such as Muskrats and waterfowl, sediment was substituted for soil in calculating the external dose, since these animals are typically in shoreline situations.

The total radiation dose to biota is the sum of the internal and external dose components for each radionuclide ($D_{int} + D_{ext}$). External exposure through the air immersion and inhalation pathway are considered to be minor compared to the ingestion pathway, and were ignored, with the exception of noble gases, which were initially considered (CSA, 2012). The external dose due to argon-41 was assessed for the terrestrial biota by directly applying the absorbed dose value from the air kerma presented in OPG's annual EMP reports. The dose coefficients and occupancy factors used in the radiological dose estimation are provided in Section 4.2.3.4.

4.2.3.2 Non-Radiological Dose Calculations

The non-radiological dose (D_{ing}) for mammals and birds was estimated using the methods described in CSA (2012), and is as follows:

$$D_{ing} = S\ C_x \cdot I_x / W$$

where,

C_x	=	concentration in the ingested item (x) (mg/kg)
I_x	=	ingestion rate of item x (kg/day)

W = body weight of consumer (kg fw)

For receptors that drink from contaminated water, such as the muskrat drinking from Frenchman's Bay, the drinking water component was considered. The concentrations in the water and the ingestion rate were in units of volume. In addition, for receptors that have incidental contaminated soil or sediment ingestion, this pathway was considered on a dry weight basis. Other ingested items (foods) were considered on a fresh weight basis. As with the radiological dose calculations, inhalation exposure is considered minor compared to the ingestion exposure, and was ignored (CSA, 2012).

4.2.3.3 Tissue Concentration Calculations

In cases where tissue concentrations (C_t) were not measured in plants, fruits, invertebrates or fish, the tissue concentrations were derived using BAFs, as per CSA N288.6, 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 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 4.2.3.4.

4.2.3.4 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).

4.2.3.4.1 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 were taken from the 2000 ERA (SENES, 2000b), 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 4.17, 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 4.17.

Table 4.17: Bird and Mammal Body Weights and Intake Rates

Receptor	Body Weight	Total Feed Intake		Dietary Components	Feed Type Fraction		Feed Intake Rate		Moisture [g]	Fraction 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/d
Trumpeter Swan	11 [a, b]	0.347 [a, b]	1.386	Aquatic plants (cattail)	1	1	0.347	1.39	0.75	3.3	1.14E-02	0.29	2.59
Ring-Billed Gull (Outfall)	0.7 [a]	0.0498 [a]	0.202	Aquatic plants (cattail)	0.20	0.20	0.0101	0.040	0.75	3.3	1.64E-03	0.0465	0.311
				Fish (pelagic forage)	0.60	0.61	0.0302	0.121	0.75				
				Soil invertebrates (earthworms)	0.10	0.07	0.0034	0.020	0.83				
				Small mammals (meadow vole)	0.10	0.12	0.0060	0.020	0.70				
Ring-Billed Gull (Frenchman's Bay)	0.7 [a]	0.0498 [a]	0.195	Aquatic plants (cattail)	0.20	0.20	0.0098	0.039	0.75	3.3	1.64E-03	0.0465	0.311
				Fish (pelagic forage)	0.60	0.61	0.0293	0.117	0.75				
				Benthic invertebrates	0.10	0.10	0.0049	0.020	0.75				
				Muskrat	0.10	0.12	0.0059	0.020	0.70				
Common Tern	0.125 [b]	0.0150 [b]	0.060	Fish (pelagic forage)	0.90	0.90	0.014	0.054	0.75	2.0	3.00E-04	0.015	0.08
				Benthic invertebrates	0.10	0.10	0.002	0.006	0.75				
Bufflehead	0.473 [b]	0.045	0.179 [b]	Aquatic plants (cattail)	0.10	0.10	0.004	0.018	0.75	10.4	4.65E-03	0.036	0.23
				Benthic Invertebrates	0.90	0.90	0.040	0.161	0.75				
Red-winged Blackbird	0.0545 [b, j]	0.009 [c]	0.0515	Soil invertebrates (earthworms)	1	1	0.0088	0.052	0.83	7.3	6.39E-04	0.008	0.04
Red-tailed Hawk	1.224 [b, c]	0.066 [c]	0.221	Terrestrial birds (blackbird)	0.27	0.27	0.0179	0.060	0.70	3.3	2.19E-03	0.0676	0.48
				Small mammals (meadow vole)	0.73	0.73	0.0485	0.162	0.70				
Muskrat	1.175 [a, c]	0.088	0.353 [a]	Aquatic plants (cattail)	1	1	0.088	0.353	0.75	3.3	2.91E-03	0.114	0.62
Meadow Vole	0.0338 [a]	0.002	0.011 [a, h]	Terrestrial Vegetation (grass)	1	1	0.0022	0.011	0.80	2.4	5.28E-05	0.0047	0.036
Red fox	4.54 [a,c]	0.088	0.313 [b, c]	Small Mammals (Meadow Vole)	0.50	0.54	0.047	0.157	0.70	2.8	2.46E-03	0.386	1.83
				Waterfowl (Bufflehead)	0.30	0.32	0.028	0.094	0.70				
				Terrestrial Vegetation (Grass)	0.20	0.14	0.013	0.063	0.80				
White-Tailed Deer	80 [d]	2.5 [d]	12.50	Terrestrial Vegetation (grass)	1	1	2.5	12.5	0.80	2.0	5.00E-02	5.11	18.2

Notes:

a - (SENES, 2000b)

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.

4.2.3.4.2 Occupancy Factors

The fraction of time the biota resides in the PN site area, as discussed in Section 4.2.2, 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, where available, are those in the previous ERA (SENES, 2000b, 2001). 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 4.18, and are applied to the equations discussed in Section 4.2.3.1.

Table 4.18: Receptor Occupancy Factors

Aquatic Biota	OF_s	OF_{ss}	OF_w	Terrestrial Biota	OF_s	OF_{ss}
Benthic Fish		0.5	0.5	Terrestrial Plants		1
Pelagic Fish			1	Earthworm	1	
Amphibians		0.5	0.5	Red-winged Blackbird		1
Benthic Invertebrates	1			Red-tailed Hawk		1
Aquatic Plants		0.5	0.5	Meadow Vole		1
				Red Fox	0.2	0.8
				Riparian Birds		0.5
				Muskrat		0.5
				White-Tailed Deer		1

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

4.2.3.4.3 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 (CSA, 2020; IAEA, 2010) and literature sources, including those suggested in CSA N288.6-12 (CSA, 2012). The BAFs used in the assessment are presented in Table 4.19 and Table 4.20. Bioaccumulation factors for tritium and carbon-14 are calculated using the specific activity model, which is discussed in Section 4.2.3.4.6 and 4.2.3.4.7. As discussed in Section 3.2.4 of the HHRA, the fish BAF for hydrazine and morpholine is based on a QSAR model by Meylan et al. 1999 (as cited in (European Commission, 2006)). There are no other hydrazine and morpholine BAFs available for other aquatic biota. No BAFs are presented for total residual chlorine as chlorine does not bioaccumulate in plants or animals (ATSDR, 2010).

For cyanide and PHC fraction F4, BAFs for transfer from soil to soil invertebrates and terrestrial plants are not warranted as these parameters do not bioaccumulate through the food chain (CCME, 1997, 2008).

Table 4.19: Bioaccumulation Factors (BAFs) for Fish, Amphibians, Benthic Invertebrates, and Aquatic Plants (L/kg fw)

COPC	Fish	Amphibian	Benthic Invertebrate	Aquatic Plant
Cobalt-60	5.40E+01[1]	5.40E+01[1]	1.10E+02[1]	7.90E+02[1]
Cesium-134	3.50E+03[1]	3.50E+03[1]	9.90E+01[1]	2.20E+02[1]
Cesium-137	3.50E+03[1]	3.50E+03[1]	9.90E+01[1]	2.20E+02[1]
Hydrazine	3.16E+00[2]	nd	nd	nd
Morpholine	3.16E+00[2]	nd	nd	nd
Copper	2.70E+02[3]	2.70E+02[3]	4.20E+01[3]	3.00E+03[3]
Aluminum	6.6E+01[3]	6.6E+01[3]	3.4E+03[3]	8.33E+02[4]
Sodium	8.40E+00[1]	8.40E+00[1]	7.3E+00[1]	1.8E+01[1]
Iron	2.40E+02[1]	2.40E+02[1]	2.8E+03[1]	3.1E+03[1]

Notes:
nd = no data available
[1] (CSA, 2020)
[2] (European Commission, 2006)
[3] (IAEA, 2010)
[4] (Thompson et al., 1972)

Table 4.20: Bioaccumulation Factors (BAFs) for Soil Invertebrates and Terrestrial Plants (kg-dw soil/kg-dw biota)

COPC	Soil Invertebrate	Terrestrial Plant
Cobalt-60	3.58E-02[4]	4.70E-02[2]
Cesium-134	8.94E-02[4]	5.30E-02[2]
Cesium-137	8.94E-02[4]	5.30E-02[2]
Arsenic	2.24E-01[1]	2.50E-01[2]
Copper	5.15E-01[1]	8.00E-01[3]
Lead	2.66E-01[1]	3.10E-02[3]
Zinc	3.2E+00[1]	1.30E+00[2]

Notes:
BAFs were converted from dw to fw where necessary using a factor of 0.17 for earthworms and 0.2 for terrestrial plant.
[1] (Sample et al., 1998) – Median uptake factors presented on Table 11 used to represent soil to earthworm BAFs
[2] (CSA, 2020) – Table G.3
[3] (IAEA, 2010) – Table 17
[4] (Beresford et al., 2008)

4.2.3.4.4 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 4.21 and Table 4.22. The transfer factors for tritium and carbon-14 were derived using specific activity methods, which are discussed in Section 4.2.3.4.6 and 4.2.3.4.7.

The CCME (CCME, 1997) indicates that cyanide does not bioaccumulate in any organisms, but is rapidly degraded by organisms at low doses. As such, the major route of exposure to cyanide for mammals and birds is through soil ingestion.

A transfer factor for petroleum hydrocarbon F4 is also not warranted. The CCME (CCME, 2008) argues that petroleum hydrocarbons do not accumulate in tissues of plants, mammals and birds. Most petroleum hydrocarbons are quickly metabolized and modified for release from the body. The major route of exposure to petroleum hydrocarbons for mammals and birds is through soil ingestion and not through consumption of plants and other animals.

Table 4.21: 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
Copper	8.09E-02	6.38E-01	2.32E+00	8.56E-01	7.36E-01
Iron	3.90E-01	3.08E+00	1.12E+01	4.13E+00	1.50E+00
Sodium	1.95E+00	1.54E+01	5.60E+01	2.06E+01	1.61E+00
Aluminum	N/A	N/A	N/A	N/A	1.61E-01

Notes:
There were no data available to determine transfer factors for hydrazine and morpholine
Radionuclide, iron and sodium transfer factors were derived from beef and poultry transfer factors from (CSA, 2020)
Aluminum transfer factor was derived from beef from (ATSDR, 2008)
Copper transfer factors were derived from beef and poultry from (Sheppard et al., 2009)

Table 4.22: Transfer Factors for Terrestrial Birds and Mammals (d/kg fw)

COPC	Red-winged Blackbird	Red-tailed Hawk	Meadow Vole	Red Fox	White-Tailed Deer
Cobalt-60	1.45E+01	1.40E+00	6.61E-01	1.68E-02	1.95E-03
Cesium-134	4.03E+01	3.90E+00	3.38E+01	8.58E-01	9.97E-02
Cesium-137	4.03E+01	3.90E+00	3.38E+01	8.58E-01	9.97E-02
Arsenic	1.79E+01	N/A	3.08E+01	N/A	9.06E-02
Copper	4.33E+00	N/A	1.05E+01	N/A	3.31E-02
Lead	6.03E+00	N/A	1.08E+00	N/A	3.17E-03
Zinc	7.01E+00	N/A	2.46E+02	N/A	7.25E-01

Notes:
Transfer factors for non-radionuclides were not required for Red-tailed Hawk and Red Fox, since tissue concentrations were not required for the exposure calculation.
Radionuclide transfer factors were derived from rabbit and poultry transfer factors from (CSA, 2020)
Arsenic transfer factors were derived from beef and poultry (CSA, 2020)
Lead (for mammals), and zinc transfer factors were derived from beef and poultry (IAEA, 2010)
Copper and lead (for birds) transfer factors were derived from beef and poultry (Sheppard et al., 2009)

4.2.3.4.5 Dose Coefficients

Radiation dose coefficients (DCs) used for terrestrial and aquatic biota are shown in Table 4.23. These DCs were taken from International Commission on Radiological Protection (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; (Brown 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 4.23: Dose Coefficients of Surrogate Receptors Used for Radiological Exposure Calculations

Radionuclide	Earthworm		Grass		Pine Tree		Insect Larvae		Seaweed	
	Internal DC	External DC (in soil)	Internal DC	External DC	Internal DC	External DC	Internal DC	External DC	Internal DC	External DC
	(µGy/hr)/(Bq/kg fw)	(µGy/hr)/(Bq/kg fw)	(µGy/hr)/(Bq/kg fw)	(µGy/hr)/(Bq/kg fw)	(µGy/hr)/(Bq/kg fw)	(µGy/hr)/(Bq/kg fw)	(µGy/hr)/(Bq/kg fw)	(µGy/hr)/(Bq/kg fw)	(µGy/hr)/(Bq/kg fw)	(µGy/hr)/(Bq/kg fw)
Carbon-14	2.83E-05	0.00E+00	2.83E-05	0.00E+00	2.83E-05	0.00E+00	2.80E-05	8.20E-07	2.83E-05	2.17E-07
Cobalt-60	7.50E-05	1.29E-03	7.50E-05	1.79E-05	7.50E-04	5.42E-06	5.20E-05	1.40E-03	8.75E-05	1.42E-03
Cesium-134	1.08E-04	8.33E-04	1.04E-04	1.21E-05	5.83E-04	3.58E-06	7.20E-05	9.20E-04	1.13E-04	8.75E-04
Cesium-137	1.42E-04	3.04E-04	1.42E-04	4.58E-06	3.25E-04	1.29E-06	9.80E-05	3.70E-04	1.38E-04	3.29E-04
Tritium	5.76E-06	0.00E+00	5.76E-06	0.00E+00	5.76E-06	0.00E+00	5.78E-06	2.40E-13	5.76E-06	2.33E-09
Iodine-131	1.13E-04	1.92E-04	1.08E-04	3.08E-06	2.46E-04	9.17E-07	8.70E-05	2.40E-04	1.13E-04	2.21E-04

Radionuclide	Rat			Trout	
	Internal DC (µGy/hr)/(Bq/kg fw)	External DC (on soil) (µGy/hr)/(Bq/m^3)	External DC (in soil) (µGy/hr)/(Bq/kg fw)	Internal DC (µGy/hr)/(Bq/kg fw)	External DC (in water) (µGy/hr)/(Bq/kg fw)
Carbon-14	2.83E-05	0.00E+00	0.00E+00	2.83E-05	1.79E-08
Cobalt-60	1.67E-04	7.92E-06	1.21E-03	2.13E-04	1.29E-03
Cesium-134	1.71E-04	5.00E-06	7.92E-04	2.04E-04	7.92E-04
Cesium-137	1.71E-04	1.88E-06	2.83E-03	1.83E-04	2.83E-04
Tritium	5.76E-06	0.00E+00	0.00E+00	5.76E-06	3.54E-13
Iodine-131	1.29E-04	1.29E-06	1.79E-04	1.38E-04	1.92E-04

Radionuclide	Tadpole		Duck		
	Internal DC (µGy/hr)/(Bq/kg fw)	External DC (in water) (µGy/hr)/(Bq/kg fw)	Internal DC (µGy/hr)/(Bq/kg fw)	External DC (on soil) (µGy/hr)/(Bq/m^3)	External DC (in water) (µGy/hr)/(Bq/kg fw)
Carbon-14	2.83E-05	2.29E-07	2.83E-05	0.00E+00	2.83E-05
Cobalt-60	6.25E-05	1.42E-03	2.38E-04	7.50E-06	6.25E-05
Cesium-134	9.58E-05	9.17E-04	2.21E-04	5.00E-06	9.58E-05
Cesium-137	1.33E-04	5.42E-07	1.88E-04	1.79E-06	1.33E-04
Tritium	5.76E-06	1.33E-11	5.76E-06	0.00E+00	5.76E-06
Iodine-131	1.04E-04	2.25E-04	1.42E-04	1.21E-06	1.04E-04

Notes:
Earthworm, grass, pine tree, seaweed, rat, trout, tadpole and duck DCs from (ICRP, 2008)
Insect larvae DC from ERICA Assessment Tool 1.2.1 (Brown et al., 2008)
Grass is the surrogate species for all terrestrial plants other than pines, insect larvae used for benthic invertebrates, seaweed for aquatic plants, tadpole is the surrogate for frogs, rat for mammals, and duck for all birds.
Noble gases are assessed using measured values from OPG's EMP and do not require DCs.

4.2.3.4.6 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 (CSA, 2020) and as recommended in Clause 7.3.4.3.7 of CSA N288.6-12 (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 4.24.

Table 4.24: 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)
Turtles and Frogs	L/kg fw	7.50E-01	1.4E-01	5.70E+03	(CSA, 2020) using fish as a surrogate
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)

BAFs for terrestrial plants and soil invertebrates are not required for modelling tritium but are handled through the transfer from air as outlined in Clause 6.4.6.2 (CSA, 2020).

For HTO and OBT, the majority of the tritium taken into the animal is from water ingestion and food consumption. The soil 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):

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

where,

k_{aw} = fraction of water from contaminated sources
f_{w-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

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:

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

where,

k_{af} = fraction of food from contaminated sources
f_{w-pw} = fraction of the animal water intake derived from water in the 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
$1\text{-}DW_a$ = 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 birds or mammals 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 the 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 4.25.

Table 4.25: 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
Red-winged Blackbird	0.22	0.65	0.121	0.1
Red-tailed Hawk	0.22	0.65	0.121	0.1
Red Fox	0.413	0.509	0.071	0.11
Meadow Vole	0.413	0.509	0.071	0.11
White-tailed Deer	0.413	0.509	0.071	0.11

Notes:
f_{w_w}, f_{w_pw}, f_{w_dw}, and f_{OBT} are from Table 16 and 17 in CSA N288.1 (2014, 2020)

4.2.3.4.7 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 (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). The fish stable carbon content was considered appropriate for frogs and turtles. 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). For terrestrial invertebrates, the stable carbon content for zooplankton and benthic insects was adjusted to a terrestrial invertebrate dry to fresh weight ratio of 0.17 (CSA, 2020).

The stable carbon concentrations for terrestrial plants, fruits and terrestrial invertebrates are presented in Table 4.26.

Table 4.26: 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	
insects/earthworms	120	
small mammals	201	
benthic invertebrates	120	
birds	244	
vegetation	100	

4.2.4 Dispersion Models

4.2.4.1 Atmospheric Dispersion Model for Non-Radiological Contaminants

AERMOD was used to estimate the hydrazine concentration in air at the PN site boundary (Golder, 2015; Ortech, 2019b, 2019a, 2020, 2021) and to estimate concentrations of air COPCs at the site boundary to support the 2018-2020 ESDM. For the 2016-2017 reporting periods the air dispersion model used to support the ESDM as the MECP-approved model in the Appendix to O. Reg. 346/90. Results are reported in this risk assessment. Uncertainties in the model are discussed in Section 3.2.7.

4.2.4.2 CSA N288.1 Atmospheric Dispersion Model for Radiological Contaminants

The concentration of COPCs in air is determined by the atmospheric release rate from the point of emission and a transfer parameter from the source to the air at a given receptor location (P_{01}). The long-term average value of the transfer parameter P_{01} is calculated based on a continuous release using a sector-averaged version of the Gaussian plume model. The model assumes that a laterally uniform concentration of radionuclides is distributed in each wind sector since wind meanders over prolonged periods of time. The atmospheric model is governed by the following mathematical equation:

$$P_{01}=\frac{\sqrt{2}}{\sqrt{\pi}x\Delta\theta}\sum_{i,k}\left[\frac{F_{ijk}D_k}{u_k\Sigma_{zi}}\exp\left(\frac{-H_{ik}^2}{2\Sigma_{zi}^2}\right)\right]$$

where:

P_{01} = ground level transfer factor for receptor j (s/m^3)
x = distance between the source and receptor j (m)
Δθ = width of the sector over which the plume spreads (radians)
F_{ijk} = triple joint frequency of occurrence of stability class i and wind speed class k when the wind blows into the sector containing receptor j
D_k = factor that takes account of decay and ingrowth for wind speed class k
H_{ik} = effective release height for stability class i and wind speed class k (m)
Σ_{zi} = vertical dispersion parameter for stability class i, including spreading due to building wake effects (m), where z refers to the vertical axis
u_k = mean wind speed for speed class k (m/s)

The air plume characteristics and surface roughness lengths used in the EcoRA IMPACT model are consistent with those defined in the PN 2016 DRL report (Tables 9 and 10, respectively in OPG, 2017i)

COPCs in dust are dispersed and deposited to the soil. The soil model in CSA N288.1 is a dynamic model that incorporates the input of activity due to wet and dry deposition from air and loss due to decay, erosion, leaching, volatilization, and cropping. The transfer of COPCs from the air and soil to terrestrial plants is calculated using air-to-plant and soil-to-plant transfer factors. The COPCs are then transferred to terrestrial animals via inhalation (air), ingestion of water and food, and incidental ingestion of soil and sediment.

Meteorological data (wind speed, direction and frequency) used for the assessment was data from 2016-2020 from the 10 m meteorological tower at the PN site, as shown in Figure 2.9.

4.2.4.3 Aquatic Dispersion Model

The concentration of COPCs in water were based on measured concentrations in the environment; therefore all water concentrations were dictated in the IMPACT model and the aquatic dispersion model was not used in the EcoRA.

4.2.5 Exposure Point Concentrations and Doses

4.2.5.1 Exposure Point Concentrations

The surface water, sediment and soil concentrations used for the exposure evaluation are listed in Table 4.28 and Table 4.30 for radiological and chemical COPCs, respectively. The emissions used for modelling are provided in Table 4.27. The exposure values are based on monitoring and measurements at the PN site. There are media-specific concentrations used for the various receptors and receptor locations. The radiological tissue concentrations for each VEC are listed on Table 4.29.

Information from 2016 to 2020 on the radiological contaminants discharged in air and liquid effluents into the environment was available from quarterly Safety Performance Indicator reports from 2016 to 2020.

The airborne contaminants are reported as tritium oxide, noble gases, radioiodines, gross beta-gamma, and carbon-14 from combined PN U1-4 and U5-8 emissions. The gross beta/gamma radionuclide with the most restrictive DRL for terrestrial biota is cobalt-60 and, consistent with the annual dose calculations for human receptors, was chosen to represent beta/gamma emissions in risk calculations. As other radioiodines have short half-lives, Iodine-131 was chosen to represent all radioiodines.

The waterborne contaminants are reported as tritium, carbon-14 and gross beta/gamma. The limiting gross beta/gamma radionuclide determined to result in the higher relative dose via aquatic release is cesium-134, and was chosen to represent the gross beta/gamma emissions in the risk calculations. Appendix C describes the evaluation completed to determine the limiting gross beta/gamma radionuclide (see Appendix C). The aquatic biota at the outfall is assumed to be exposed to radionuclide concentrations equal to the total effluent discharge concentration from the CCW from PN U1-4 and PN U5-8 combined. Although lake surface water data were available for radionuclides from the 2015 baseline environmental monitoring program, results were generally below detection limits. Emissions data from the EMP provided measured concentrations at lower detection limits; therefore, EMP emissions data were used as exposure point concentrations in the EcoRA.

As part of the baseline environmental monitoring program, water and sediment data were collected from the north and south ends of Frenchman's Bay, as discussed in Section 4.1.3.2.4. The concentrations observed at Frenchman's Bay reflect the contribution from PN in addition to urban runoff into the wetland. A surface water model has been developed for PN to support Pickering Safe Storage Project activities (Golder and Ecometrix, 2017). The surface water model is based on current and temperature data from 2011 and 2012, and is used to predict water concentrations at the inlet to Frenchman's Bay and Ajax WTP based on a tracer concentration for any parameter of 1 mg/L (Golder and Ecometrix, 2017). A mass-balance model has also been used to predict concentrations in Frenchman's Bay, assuming a completely mixed embayment, with inputs from lake exchange and tributaries. Based on the surface water model and mass balance model, the dilution factors for PN U1-4 and U5-8 releases from the outfall to the inlet to Frenchman's Bay and inside the bay are approximately 7 and 9 respectively.

The assessment at Frenchman's Bay presented in the EcoRA focuses on parameters identified as COPCs in lake water samples and Frenchman's Bay water samples. The chemical COPCs include: hydrazine, morpholine, and total residual chlorine (See Appendix A, Table A.6); copper (See Appendix A, Table A.7); aluminum, iron, and sodium (see Appendix A, Table A.9). The radiological COPCs include tritium, carbon-14, cobalt-60, cesium-134, and cesium-137.

A longer list of COPCs was identified in Frenchman's Bay sediment samples; however, many of those COPCs are not facility related and the contributions from PN to the sediment concentrations at Frenchman's Bay are small. A comparison between the exposure/risk results from observed water and sediment concentrations at Frenchman's Bay, and PN contributions only, is provided in Appendix E for all parameters exceeding screening levels.

The maximum and upper confidence limit on mean (UCLM) concentrations for each assessment area are shown in Table 4.28 and Table 4.30. The maximum and UCLM concentrations are used in Section 4.4 to calculate risk estimates that encompass the upper range of possible values. The maximum is relevant for sessile organisms, since one of them may reside at the maximum concentration, while the mean, or conservatively an upper 95% confidence limit on the mean (UCLM), is relevant for mobile organisms which move around the area.

Some mobile receptors have home ranges smaller than the assessment area, while others have home ranges larger than the assessment area. For receptors with smaller home ranges, some individuals may be exposed at the UCLM concentration, but most individuals will receive less exposure, so the UCLM is a conservative exposure value.

The UCLM represents a reasonable upper bound on the mean, considering the statistical uncertainty in its estimation. This uncertainty in the exposure of mobile organisms is discussed in Section 4.2.6, and the corresponding uncertainty in risk estimates is discussed in Section 4.4.5.

In instances where there were non-detects in the dataset and they were not predominant (<15%), they were replaced with a one-half MDL value, and a mean value was determined. However, when more than 50% of the dataset was comprised of non-detects, there is no method to provide a reliable estimate of the mean (CSA, 2012). To be conservative, in these instances the detection limit was considered to be a measured value and was used in the dataset to calculate the mean, likely overestimating the concentrations found at the location. In those situations, the maximum value may be most appropriate.

Table 4.27: Emissions to Air used to Model Exposure Point Concentrations

COPC	Air Emission Rate (Bq/s)	
	Maximum	UCLM
Tritium Oxide	4.61E+07	1.91E+07
Noble Gases	1.22E+07	2.70E+06
Radioiodines (I-131)	1.98E+00	3.43E-01
Gross Beta-Gamma (Co-60)	1.82E+02	3.25E+00
C-14	4.02E+05	8.06E+04

Notes
Calculated from weekly emissions data collected during the 2016-2020 period

Table 4.28: Exposure Point Concentrations for Radiological COPCs

COPC	Outfall						PN Site		Frenchman's Bay			
	Surface Water (1)		Sediment (2)		White Sucker (3)		Soil (4)		Surface Water (5,6,7)		Sediment (8)	
	Bq/L		Bq/kg dw Bq/L (HTO/pore water)		Bq/kg fw		Bq/kg dw		Bq/L		Bq/kg dw Bq/L (HTO/pore water)	
	Maximum	UCLM	Maximum	UCLM	Maximum	UCLM	Maximum	UCLM	Maximum	UCLM	Maximum	UCLM
Carbon-14	3.70E-03	8.02E-04	1.14E+00	1.00E+00	3.71E+01	3.21E+01	5.57E+00	3.32E+00	4.48E-01	2.36E-01	2.24E+01	1.18E+01
Cesium-134	9.06E-01	5.60E-02	8.61E+03	5.32E+02	-	-	<1.00E+00	<1.00E+00	<1.00E-01	<1.00E-01	<3.30E+00	<3.15E+00
Cesium-137	-	-	-	-	2.90E-01	1.54E-01	<1.00E+00	<1.00E+00	<1.00E-01	<1.00E-01	2.20E+01	6.92E+00
Cobalt-60	-	-	< 5.00E-01	3.60E-01	-	-	<1.00E+00	<1.00E+00	<1.00E-01	<1.00E-01	6.00E+00	1.56E+00
Tritium	2.09E+02	9.51E+01	0.00E00	0.00E00	1.19E+01	4.28E+00	4.86E+02	3.48E+02	5.01E+01	3.33E+01	-	-

Notes:
(1) Surface water at the outfall is based on monthly effluent Gross β/γ activity and calculated from monthly CCW flow rates from PN U1-4 and PN U5-8 from 2016-2020. Gross β/γ is represented by Cesium-134 (see Appendix C).
(2) Sediment at the outfall for Carbon-14 and Cobalt-60 is based on sediment results reported in 2006-2009 EMP reports. Sediment for Cesium-134 is modelled based on water concentration and a partitioning coefficient (Kd).
(3) White Sucker tissue concentrations at the outfall are based on fish collected during the 2016-2020 EMP monitoring period
(4) Soil concentrations at the PN site are based on the results of the 2015 baseline sampling program
(5) C-14 was not measured in surface water, concentration is calculated from sediment concentration using a partitioning coefficient (sediment concentration/Kd)
(6) Surface water concentrations of Cs-134, Cs-137 and Co-60 at Frenchman's Bay are based on measured concentrations during the 2015 sampling program
(7) Surface water concentrations of tritium at Frenchman's Bay are based on measured concentrations during the 2016-2020 EMP monitoring period
(8) Sediment concentrations at Frenchman's Bay are based on the combined results of the 2015 baseline sampling program (n=22) and 2019 EMP monitoring data (n=8).
"-" = no data available.

Table 4.29: Radiological Exposure Concentrations by Receptor

Location	VEC	Unit	Carbon-14		Cesium-134		Cesium-137		Cobalt-60		HTO		OBT		Iodine-131	
			Max	UCLM	Max	UCLM	Max	UCLM	Max	UCLM	Max	UCLM	Max	UCLM	Max	UCLM
Outfall	Benthic Fish	Bq/kg(fw)	3.71E+01	3.21E+01	3.17E+03	1.96E+02	2.90E-01	1.54E-01	0.00E+00	0.00E+00	1.19E+01	4.28E+00	2.21E+00	7.99E-01	NA	NA
	Pelagic Fish	Bq/kg(fw)	2.11E+01	4.57E+00	3.17E+03	1.96E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.57E+02	7.13E+01	2.93E+01	1.33E+01	NA	NA
	Benthic Invertebrate	Bq/kg(fw)	2.08E+01	4.52E+00	8.97E+01	5.54E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.57E+02	7.13E+01	2.93E+01	1.33E+01	NA	NA
	Ring-Billed Gull	Bq/kg(fw)	6.52E+03	2.99E+03	2.37E+03	1.51E+02	5.26E+00	5.26E+00	6.80E+00	6.79E+00	3.60E+03	1.50E+03	1.41E+02	5.88E+01	2.98E-06	5.16E-07
PN Site	Earthworm	Bq/kg(fw)	2.66E+02	5.34E+01	1.52E-02	1.52E-02	1.52E-02	1.52E-02	2.34E-01	1.02E-02	3.92E+03	1.62E+03	3.93E+02	1.63E+02	3.94E-03	6.82E-04
	Grass/Shrub	Bq/kg(fw)	3.17E+02	6.36E+01	1.06E-02	1.06E-02	1.06E-02	1.06E-02	2.29E+00	5.01E-02	3.78E+03	1.57E+03	3.70E+02	1.53E+02	3.94E-02	6.82E-03
	Pine	Bq/kg(fw)	3.17E+02	6.36E+01	1.06E-02	1.06E-02	1.06E-02	1.06E-02	8.99E-02	1.08E-02	3.78E+03	1.57E+03	3.70E+02	1.53E+02	9.79E-04	1.70E-04
	Red-winged Blackbird	Bq/kg(fw)	5.42E+02	1.09E+02	3.47E-01	7.49E-02	5.70E-02	5.70E-02	1.83E-01	1.67E-02	2.24E+03	9.29E+02	1.11E+02	4.62E+01	2.41E-05	4.17E-06
	Red-tailed Hawk	Bq/kg(fw)	7.11E+02	1.43E+02	4.21E-01	5.00E-02	2.55E-02	2.55E-02	2.26E-02	4.58E-03	1.31E+03	5.46E+02	2.33E+01	9.82E+00	8.36E-06	1.45E-06
	Red Fox	Bq/kg(fw)	4.34E+03	1.95E+03	1.61E+00	1.31E+00	1.35E+00	1.31E+00	1.70E-02	1.46E-02	2.27E+03	9.48E+02	9.18E+01	3.83E+01	7.58E-04	1.31E-04
	Meadow Vole	Bq/kg(fw)	6.38E+02	1.28E+02	1.50E-01	1.46E-02	5.73E-03	5.73E-03	1.67E-02	4.00E-04	1.73E+03	7.20E+02	8.66E+01	3.62E+01	4.09E-03	7.09E-04
	White-tailed Deer	Bq/kg(fw)	6.38E+02	1.28E+02	4.79E-01	4.67E-02	1.82E-02	1.82E-02	5.59E-02	1.32E-03	1.95E+03	8.10E+02	9.55E+01	3.98E+01	1.37E-02	2.37E-03
Frenchman's Bay	White Sucker	Bq/kg(fw)	2.55E+03	1.35E+03	3.50E+02	3.50E+02	3.50E+02	3.50E+02	5.40E+00	5.40E+00	3.75E+01	2.50E+01	7.01E+00	4.66E+00	NA	NA
	Lake Trout	Bq/kg(fw)	2.55E+03	1.35E+03	3.50E+02	3.50E+02	3.50E+02	3.50E+02	5.40E+00	5.40E+00	3.75E+01	2.50E+01	7.01E+00	4.66E+00	NA	NA
	Frog	Bq/kg(fw)	2.55E+03	1.35E+03	3.50E+02	3.50E+02	3.50E+02	3.50E+02	5.40E+00	5.40E+00	3.75E+01	2.50E+01	7.01E+00	4.66E+00	NA	NA
	Aquatic Plant	Bq/kg(fw)	2.64E+03	1.39E+03	2.20E+01	2.20E+01	2.20E+01	2.20E+01	7.90E+01	7.90E+01	3.75E+01	2.50E+01	5.51E+00	3.66E+00	NA	NA
	Benthic Invertebrate	Bq/kg(fw)	2.52E+03	1.33E+03	9.90E+00	9.90E+00	9.90E+00	9.90E+00	1.10E+01	1.10E+01	3.75E+01	2.50E+01	7.01E+00	4.66E+00	NA	NA
	Bufflehead	Bq/kg(fw)	1.07E+04	5.64E+03	1.60E+01	1.60E+01	1.67E+01	1.61E+01	9.22E+00	9.16E+00	7.55E+01	4.46E+01	4.54E+00	2.40E+00	3.78E-09	6.54E-10
	Common Tern	Bq/kg(fw)	5.16E+03	2.72E+03	4.10E+02	4.10E+02	4.10E+02	4.10E+02	2.80E+00	2.79E+00	5.29E+01	2.95E+01	4.54E+00	2.40E+00	3.56E-09	6.17E-10
	Trumpeter Swan	Bq/kg(fw)	5.16E+03	2.72E+03	2.30E+01	2.30E+01	2.31E+01	2.30E+01	2.96E+01	2.96E+01	5.29E+01	2.95E+01	3.33E+00	1.59E+00	4.02E-09	6.96E-10
	Ring-Billed Gull	Bq/kg(fw)	1.55E+04	8.16E+03	2.52E+02	2.52E+02	2.53E+02	2.52E+02	8.46E+00	8.45E+00	1.07E+02	6.29E+01	5.02E+00	2.65E+00	3.91E-09	6.78E-10
	Muskrat	Bq/kg(fw)	4.25E+03	2.24E+03	1.84E+01	1.84E+01	1.85E+01	1.84E+01	1.29E+00	1.29E+00	4.92E+01	2.83E+01	3.85E+00	2.03E+00	2.86E-07	4.95E-08

Table 4.30: Exposure Point Concentrations for Chemical COPCs

COPC	Outfall				PN Site				Frenchman's Bay			
	Surface Water (1,2)		Sediment (3)		Surface Water (4)		Soil (5)		Surface Water (6)		Sediment (7)	
	mg/L		mg/kg dw		mg/L		mg/kg dw		mg/L		mg/kg dw	
	Maximum	UCLM	Maximum	UCLM	Maximum	UCLM	Maximum	UCLM	Maximum	UCLM	Maximum	UCLM
Hydrazine (from CCW)	2.46E-02	1.85E-03	0.00E+00	0.00E+00	-	-	-	-	2.86E-03	2.15E-04	0.00E+00	0.00E+00
Morpholine (CCW)	1.35E-01	2.85E-03	0.00E+00	0.00E+00	-	-	-	-	1.57E-02	3.31E-04	0.00E+00	0.00E+00
TRC (from CCW)	2.40E-02	1.03E-02	0.00E+00	0.00E+00	-	-	-	-	2.79E-03	1.19E-03	0.00E+00	0.00E+00
Morpholine (Lake water)	6.00E-03	4.39E-03	0.00E+00	0.00E+00	-	-	-	-	<4.00E-03	<4.00E-03	0.00E+00	0.00E+00
Aluminum	-	-	-	-	-	-	-	-	2.70E-01	2.03E-01	1.30E+04	9.85E+03
Arsenic	-	-	-	-	1.00E-03	1.00E-03	5.80E+01	9.65E+00	-	-	-	-
Copper	8.80E-03	2.78E-03	2.38E+01	7.49E+00	2.00E-03	1.68E-03	8.30E+02	1.29E+02	2.10E-03	1.89E-03	7.40E+01	5.18E+01
Iron	-	-	-	-	-	-	-	-	5.60E-01	4.27E-01	2.10E+04	1.74E+04
Lead	-	-	-	-	5.00E-04	5.00E-04	2.30E+02	4.21E+01	-	-	-	-
Sodium	-	-	-	-	-	-	-	-	9.10E+01	7.57E+01	5.90E+02	4.19E+02
Zinc	-	-	-	-	5.50E-03	5.25E-03	3.20E+03	5.22E+02	-	-	-	-
Cyanide	-	-	-	-	-	-	3.30E-01	2.18E-01	-	-	-	-
PHC Fraction F4	-	-	-	-	2.00E-01	2.00E-01	5.70E+03	3.76E+03	-	-	-	-

Notes
"-" = not a COPC for this location
(1) CCW concentrations at the outfall are based on 2016-2020 ECA compliance monitoring data
(2) Surface water at the outfall is based on 2015 Lake Water Sampling Program (LW-10, LW-21, LW-9, LWE-1) and 2014 Hydrazine Samples near the outfall
(3) Sediment concentrations at the outfall were estimated from surface water concentrations using a water to sediment partitioning equation. Partition coefficients are shown in Table 4.16.
(4) Not a surface water COPC for the outfall but is included for assessment of water ingestion dose for terrestrial receptors at the PN site. Based on surface water locations LW10 and LW21 nearest to the PN U1-4 and U5-8 outfalls
(5) Soil concentrations at the PN site are based on the results of the 2015 Soil Sampling
(6) Surface water concentrations at Frenchman's Bay, from CCW outfall, are calculated with dilution factor = 9. Remaining surface water concentrations were measured at Frenchman's Bay in the 2015 Baseline Sampling Program.
(7) From 2015 Baseline Sampling Program; hydrazine morpholine, and total residual chlorine estimated using water:sediment partitioning

4.2.5.2 Exposure Doses

The exposure concentrations presented in Section 4.2.5.1, along with the exposure factors in Section 4.2.3.4, were applied to the equations in Section 4.2.3 to estimate the radiological dose to all biota and non-radiological dose to birds and mammals. The estimated radiological doses are presented in the risk characterization Section in Table 4.40. Radiological doses for noble gases (represented by Argon-41) contributing to total dose considered air kerma rates measured as part of the annual EMP (OPG, 2017f, 2018h, 2019e, 2021g, 2021c), as shown in Table 4.31. The estimated chemical doses are presented in Table 4.32 and Table 4.33.

Table 4.31: Air Kerma Rates for Terrestrial and Riparian Biota (mGy/d)

Location	Max	UCLM
Outfall (1)	7.05E-05	9.82E-06
PN Site (1)	7.05E-05	9.82E-06
Frenchman's Bay (2)	9.84E-06	3.71E-06

Notes:
(1) Based on 2016-2020 EMP monitoring for Argon-41 for PN site locations (P2, P3, P4, P6, P7, P10, P11)
(2) Based on 2016-2020 EMP monitoring for Argon-41 for PN site locations (P8)

Table 4.32: Estimated Non-Radiological Dose for Riparian Birds and Mammals at PN Outfall and Frenchman's Bay (mg/kg·d)

COPC		PN Outfall	Frenchman's Bay[2]				
		Ring-Billed Gull	Muskrat	Trumpeter Swan	Bufflehead	Common Tern	Ring-Billed Gull
Hydrazine from CCW[1]	Max	1.51E-02	2.79E-04	7.66E-05	2.16E-04	1.12E-03	1.71E-03
	UCLM	1.13E-03	2.10E-05	5.76E-06	1.63E-05	8.45E-05	1.28E-04
Morpholine from lake water[1]	Max	3.67E-03	3.90E-04	1.07E-04	3.02E-04	1.57E-03	2.38E-03
	UCLM	2.69E-03	3.90E-04	1.07E-04	3.02E-04	1.57E-03	2.38E-03
Morpholine from CCW	Max	4.97E-01	1.53E-03	4.20E-04	1.19E-03	6.17E-03	9.36E-03
	UCLM	3.74E-01	3.23E-05	8.86E-06	2.50E-05	1.30E-04	1.97E-04
Copper	Max	3.38E+00	2.07E+00	8.71E-01	9.97E-01	1.13E-01	6.73E-01
	UCLM	8.71E-01	1.83E+00	7.68E-01	7.51E-01	9.23E-02	5.70E-01
Chlorine (TRC) from CCW	Max	5.17E-01	4.22E-02	1.77E-02	1.58E-01	3.61E-02	6.74E-02
	UCLM	2.21E-01	1.80E-02	7.56E-03	6.75E-02	1.55E-02	2.88E-02
Aluminum	Max	N/A	9.97E+01	4.19E+01	4.49E+02	2.20E+01	7.22E+01
	UCLM	N/A	7.50E+01	3.15E+01	3.38E+02	1.66E+01	5.44E+01
Sodium	Max	N/A	5.02E+02	2.09E+02	3.01E+02	9.91E+01	2.72E+02
	UCLM	N/A	4.17E+02	1.74E+02	2.50E+02	8.24E+01	2.26E+02
Iron	Max	N/A	5.73E+02	2.41E+02	8.06E+02	4.87E+01	2.41E+02
	UCLM	N/A	4.41E+02	1.85E+02	6.29E+02	3.80E+01	1.87E+02

Notes:
[1] Doses calculated only account for ingestion of water, sediment and fish/frog ingestion (as applicable) due to the lack of information on tissue concentrations of hydrazine and morpholine in other foods.
[2] Max and mean dose for morpholine and TRC are generally equivalent for most receptors since surface water concentrations were generally measured below the detection limit.

Table 4.33: Estimated Non-Radiological Dose for Terrestrial Birds and Mammals at the PN Site (mg/kg·d)

COPC		Meadow Vole	Red-winged Blackbird	Red Fox	Red-Tailed Hawk	White-Tailed Deer
Arsenic	Max	1.03E+00	2.77E+00	1.26E-01	3.47E+00	4.89E-01
	UCLM	1.72E-01	4.61E-01	3.59E-02	5.78E-01	8.15E-02
Copper	Max	4.45E+01	7.84E+01	2.83E+00	4.67E+01	2.13E+01
	UCLM	6.94E+00	1.22E+01	4.43E-01	7.28E+00	3.31E+00
Lead	Max	8.23E-01	1.25E+01	1.46E-01	1.29E+01	3.67E-01
	UCLM	1.51E-01	2.29E+00	2.72E-02	2.36E+00	6.71E-02
Zinc	Max	2.76E+02	1.68E+03	9.23E+01	2.08E+02	1.32E+02
	UCLM	4.50E+01	2.75E+02	1.51E+01	3.40E+01	2.15E+01
Cyanide	Max	5.16E-04	3.87E-03	1.78E-04	1.82E-02	2.06E-04
	UCLM	3.40E-04	2.55E-03	1.18E-04	1.20E-02	1.36E-04
Petroleum Hydrocarbon F4	Max	8.93E+00	6.69E+01	3.10E+00	3.15E+02	3.58E+00
	UCLM	5.90E+00	4.41E+01	2.05E+00	2.08E+02	2.36E+00

4.2.5.2.1 Pickering Waste Management Facility

The dose rate for ecological receptors in close proximity to the PWMF could be up to 0.5 µGy/h (0.012 mGy/d), assuming full capacity of the PWMF, as discussed in Section 4.1.3.5.1.

The dose rate to any ecological VEC at the closest PN property boundary would be much lower than 0.5 µGy/h (0.012 mGy/d).

The above assessment is conservative as it assumes the receptor is always located at the PWMF and does not incorporate an occupancy factor based on the fraction of time a receptor is likely to be in close proximity to the PWMF.

4.2.6 Uncertainties in the Exposure Assessment

Uncertainties in the exposure assessment include the representativeness of media concentrations used in the assessment at each location. The UCLM concentrations of COPCs were used for each location and media, where possible, and are considered to be representative for all mobile receptors. Maximum concentrations found in various sources were also used as an upper bound on exposure. These values are, by definition, not representative for mobile organisms that can move around the site, effectively averaging their exposure concentrations. Maximum values are representative for exposures of any sessile organisms that reside at the location of the maximum value.

Although the majority of data comes from measured values, partitioning coefficients were used to estimate COPC concentrations in media that were not measured (i.e., water concentration for carbon-14 was estimated from a sediment concentration). 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, e.g., fish values used for frog. The partition coefficients and BAFs used for the exposure assessment were not site-specific, and 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 (RBE) of 2 was applied to the low beta component of the tritium DCs, as recommended by CSA N288.6; however, a range of 1 to 3 is used in the literature. Therefore, the tritium internal dose coefficient for all ecological receptors could be either higher or lower, modified by factors of 1.43 or 0.57, respectively.

Radiation doses were calculated from measured concentrations of radionuclides such as cobalt-60, cesium-134, and cesium-137 in water. The majority of samples resulted in 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.

Uncertainty in the HTO air and soil pore water predictions arises from inherent uncertainty in the air model in IMPACT. The model reports an average concentration, and typically over-predicts this concentration by a factor of 1.5 (COG, 2013). Uncertainty in the predictions arises from the following assumptions made in the air model:

- The activity in the plume has a normal distribution in the vertical plane;
- The effects of building-induced turbulence on the effective release height and plume spread have been generalized, while data suggest that effects of building wakes vary substantially depending upon the geometry of the buildings and their orientation with respect to wind direction.
- A given set of meteorological and release conditions leads to a unique air concentration, where in reality measured concentrations can vary by a factor of 2 under identical conditions.

Average dilution factors from the surface water model were used to estimate concentrations at Frenchman's Bay to determine the PN station contribution to exposure at Frenchman's Bay. Based on maximum and minimum lake water conditions, on an hourly basis, the dilution factors from PN to inside Frenchman's Bay can range from 4 to 24, with an average dilution factor of 9. The average value is considered to be realistic for chronic exposure estimates. The lake conditions (i.e. water levels, water temperature, and current speeds) that were used to establish bounding conditions for the surface water model supporting the 2017 PEA were reviewed recently in a 2022 updated addendum report (Ecometrix, 2023). The review found that the differences between recent conditions over the 2016-2020 period and the conditions in 2011-2012 are minor, and that the dilution factors developed from the surface water model are still applicable for use.

The main uncertainties and assumptions associated with the exposure assessment are summarized in Table 4.34.

Table 4.34: Summary of Major Uncertainties in the Ecological Exposure Assessment

Risk Assessment Assumption	Justification	Over/Under Estimate Risk?
Average dilution factors from the surface water model were used to estimate water concentrations at Frenchman's Bay to determine station contribution.	Based on maximum and minimum lake water conditions the dilution factors from PN to Frenchman's Bay can range from 4 to 24, with an average dilution factor of 9.	Neither (value is a best estimate)
Kds, BAFs, intake rates, etc. are from literature when measured information as not available	Reputable literature sources were used	Neither (value is best estimate)
BAF (fish) for hydrazine is based on QSAR model and not measured bioaccumulation data.	Limited information exists on bioaccumulation of hydrazine, although it is expected to be low. Only one study (Slonim and Gisclard, 1976) exists on hydrazine bioaccumulation, and there is large uncertainty surrounding the methods and results.	Neither (value is best estimate)
BAF (fish) for morpholine is based on QSAR model and not measured bioaccumulation data.	No information in literature regarding morpholine BAF, although it is not expected to bioaccumulate.	Neither (value is best estimate)
Dose coefficients for each receptor were not adjusted for exact VEC body size and dimensions	Surrogates selected with attention to similar body size and exposure habits.	Neither (value is best estimate)

4.3 Effects Assessment

The potential for ecological effects from COPC exposure at each location (Section 4.1.3) was assessed by comparing the exposure levels to toxicological, radiation, and thermal benchmarks. These benchmarks values (BVs) are taken from literature and are compared to the exposure values (EVs) to determine the potential for adverse ecological effects.

4.3.1 Toxicological Benchmarks

Water concentration benchmarks for aquatic biota are summarized in Table 4.35, and were generally LCVs obtained from Suter and Tsao (Suter and Tsao, 1996). As a general rule, toxicity benchmarks were higher than screening values since toxicity benchmarks represent exposure levels associated with adverse effects, whereas screening values typically represent no effect levels. The toxicity benchmarks for copper for aquatic plants and iron for benthic invertebrates were the CCME water quality guidelines instead of the LCVs from Suter and Tsao (Suter and Tsao, 1996), since the LCVs were lower than the CCME water quality guidelines, and the guidelines are considered to be protective.

For assessment of benthic invertebrates toxicity benchmarks have been presented as water concentrations. Benthic invertebrates may reside on the sediment surface where they are exposed to contaminant concentrations in the water column or they reside in the sediment. The latter frequently pump water through their burrows exposing them to aqueous contaminants. In addition, sediment toxicity benchmarks, (MOECC LELs) were also used to assess to assess toxicity to benthic invertebrates (Table 4.35).

For hydrazine, the aquatic toxicity benchmark values were taken from the Federal Environmental Quality Guidelines (EC, 2013). Morpholine aquatic toxicity benchmark values were taken from WHO (WHO, 1996). Since the benchmarks listed by EC for hydrazine (for fish and benthic invertebrates) and those listed by WHO for morpholine are acute, they were converted to chronic benchmarks by dividing by a factor of 10 (CCME, 1999; Suter et al., 1993). Chronic benchmarks are appropriate for hydrazine and morpholine, as exposure is based on a continuous release.

Sodium was considered to be essentially non-toxic for birds and mammals, as noted by Health Canada (HC, 1992) for people. It is effectively regulated in the body and has not been associated with adverse effects in birds and mammals at environmental concentrations.

Terrestrial plant and invertebrate benchmarks (Table 4.37) are based on soil concentrations. The values are Canadian soil quality guidelines (industrial soil contact values) (CCME, 1999), provincial soil quality guidelines (industrial plant and soil organism values) (MECP, 2011) or Lowest Observable Effect Concentration (LOEC) soil concentrations from Efroymson et al. (Efroymson et al., 1997b, 1997a). The Efroymson values are specific to either earthworms (Efroymson et al., 1997a) or plants (Efroymson et al., 1997b) but are conservative screening levels. Where an Efroymson value was higher than the more stringent of the CCME or MOECC guideline values, which occurred only for earthworms, the Efroymson value was used as the benchmark, because it was specific to the terrestrial invertebrate indicator species (earthworm) selected for the EcoRA.

However, if the Efroymson value was lower than the more stringent of the CCME or MOECC guideline values, then the more stringent guideline value was used as a benchmark, because these guidelines are considered by the responsible authorities to be adequately protective of plants and soil organisms.

The benchmark values for birds and mammals (Table 4.38 and Table 4.39) are based on doses. The benchmark doses used are the LOAEL values from Sample et al. (Sample et al., 1996), EC/HC (EC and HC, 2011) for hydrazine, and WHO (WHO, 1996) for morpholine. There were no data available for the toxicity of hydrazine and morpholine for birds, and iron and sodium for mammals and birds. Hydrazine and morpholine are concerns in the aquatic environment, but due to their rapid degradation in the aquatic system and low octanol-water partition coefficient, the bioaccumulation of hydrazine and morpholine in the food chain is unlikely (EC and HC, 2011). Petroleum hydrocarbon F4 is not a toxicological concern for mammals and birds; therefore TRVs are not warranted (CCME, 2008). The wildlife TRVs recently released by ECCC (FCSAP, 2021) included mammalian and avian TRVs for arsenic, copper, lead and zinc. The TRVs identified by ECCC were not adopted for use in the ERA update because: (1) the mammalian TRVs and avian TRVs for lead and zinc were based on US EPA data sets for which a NOAEL-based approach was used to derive the TRV. The TRV was thus considered too conservative for the target level of protection; (2) the avian TRV for arsenic was based on acute exposures, whereas the TRV used in Sample et al (1996) was based on a chronic study; and (3) the avian TRV for copper was derived with the use of an uncertainty factor which obscures the level of protection, which was identified as generally not recommended by FCSAP.

Table 4.35: Toxicological Benchmarks for Aquatic Receptors

COPC	Receptor	Water TRV (mg/L)	Endpoint	Test Species	Reference
Aluminum	Fish and Frog	3.29E+00	LCV	28-day embryo-larval tests with *Pimephales promelas*	Kimball, n.d. (cited in (Suter and Tsao, 1996))
	Aquatic Plant	4.60E-01	LCV	4-day *Selenastrum capricornutum*	U.S. EPA, 1988 (cited in (Suter and Tsao, 1996))
	Benthic Invertebrate	1.90E+00	LCV	*Daphnia magna*	McCauley et al., 1986 (cited in (Sample et al., 1996))
Chlorine (TRC)	Fish and Frog	5.90E-03	96h LC_{50} converted to EC_{20}	Rainbow Trout (*O. mykiss*)	(Fisher et al., 1999) (cited in CCME, 1999a)
	Aquatic Plant	5.00E-03	LAV converted to EC_{20}	Growth of *Myriophyllum spicatum*	Watkins and Hammerschlag, 1984 (cited in (CCME, 1999))
	Benthic Invertebrate	3.20E-03	48h LC_{50} converted to EC_{20}	*Daphnia magna*	(Fisher et al., 1999) (cited in (CCME, 1999))
Copper	Fish and Frog	3.80E-03	LCV	Early life stage test on Brook Trout (*Salvelinus fontinalis*)	Sauter et al., 1976 (cited in (Sample et al., 1996))
	Aquatic Plant	2.00E-03	Water quality guideline	-	(CCME, 1999)
	Benthic Invertebrate	6.07E-03	LCV	*Gammarus pseudolimnaeus*	Arthur and Leonard, 1970, (cited in (Sample et al., 1996))
Iron	Fish and Frog	1.30E+00	LCV	Mortality Rainbow Trout	Amelung, 1981 (cited in (Suter and Tsao, 1996))
	Aquatic Plant	1.49E+00	EC_{50} converted to EC_{20}	Growth of *Lemna minor*	Wang, 1986 (cited in (BC MOE, 2008))
	Benthic Invertebrate	3.00E-01	Water quality guideline	-	(CCME, 1999)
Sodium	Fish and Frog	1.15E+02	EC_{10} (Na component of Na_2SO_4)	Developmental effects on *Oncorhynchus mykiss*	(Elphick et al., 2011)
	Aquatic Plant	1.71E+02	EC_{25} (Na component of Na_2SO_4)	Growth of *Fontinalis antipyretica*	(Elphick et al., 2011)

COPC	Receptor	Water TRV (mg/L)	Endpoint	Test Species	Reference
	Benthic Invertebrate	6.80E+02	LCV	Reproductive effects on *Daphnia magna*	Biesinger and Christensen, 1972 (cited in (Suter and Tsao, 1996))
Hydrazine	Fish and Frog	6.1E-02	LC_{50} (96 hour) converted to chronic	Common guppy (*Lebistes rericulatus*)	Slonim, 1977 (cited in (EC, 2013))
	Aquatic Plant	2.60E-03	FEQG (HC_5 acute, converted to chronic)	-	(EC, 2013)
	Benthic Invertebrate	4.00E-03	LC_{50} (48 hour) converted to chronic	Amphipod (*Hyalella azteca*)	Fisher et al., (cited in (EC, 2013))
Morpholine	Fish and Frog	1.80E+01	LC_{50} (96 hour) converted to chronic	Mortality Rainbow Trout (*Oncorhynchus mykiss*) (low hardness)	(WHO, 1996)
	Aquatic Plant	2.80E+00	EC_{50} (96 hour) converted to chronic	Impairment/mortality Algae (*Selenastrum capricornutum*)	(WHO, 1996)
	Benthic Invertebrate	1.00E+01	EC_{50} (24 hour static) converted to chronic	*Daphnia magna*	(WHO, 1996)

Table 4.36: Toxicological Benchmarks for Benthic Invertebrates

COPC	Benthic Invertebrate (mg/kg dw)	Reference
Copper	1.60E+01	Sediment LEL (MECP, 2011)
Iron	2.12E+04	Sediment LEL (MECP, 2011)

Table 4.37: Toxicological Benchmarks for Soil for Terrestrial Invertebrates and Plants

COPC	Soil Invertebrate (mg/kg)	Reference	Terrestrial Plant (mg/kg)	Reference
Arsenic	6.00E+01	(Efroymson et al., 1997a)	2.60E+01	(CCME, 1999)
Copper	9.10E+01	(CCME, 1999)	1.00E+01	(Efroymson et al., 1997b)
Lead	6.00E+02	(CCME, 1999)	6.00E+02	(CCME, 1999)
Zinc	2.00E+02	(Efroymson et al., 1997a)	2.00E+02	(CCME, 1999)
Cyanide	8.00E+00	(CCME, 1997)	8.00E+00	(CCME, 1997)
Petroleum Hydrocarbon F4	3.30E+03	(MECP, 2011)	3.30E+03	(MECP, 2011)

Table 4.38: Selected Toxicity Reference Values for Mammals (Aquatic and Terrestrial)

COPC	Mammal LOAEL (mg/kg d)	Test Species	Endpoint	Test Duration	Reference
Aluminum	1.93E+01	mouse	reproduction	3 generations	Ondreicka et al, 1966 (cited in (Sample et al., 1996))
Arsenic	1.26E+00	mouse	reproduction	3 generations	Schroeder and Mitchner, 1971 (cited in (Sample et al., 1996))
Chlorine (TRC)	5.00E+01	rat	body weight	92 days	Furukawa et al., 1980 (cited in (HHA, 2010))
Copper	1.51E+01	mink	reproduction	375 days	Aulerich et al., 1982 (cited in (Sample et al., 1996))
Lead	8.00E+01	rat	reproduction	3 generations	Azar et al., 1973 (cited in (Sample et al., 1996))
Iron	1.82E+03	Rat	growth	91 days	(Storey and Greger, 1987)
Zinc	3.20E+02	rat	reproduction	days 1-16 of gestation	Schlicker and Cox, 1968 (cited in (Sample et al., 1996))
Hydrazine	1.87E+00	mouse	lung tumour	110-120 weeks	Roe et al., 1967; Toth, 1969, 1972 (cited in (EC and HC, 2011))
Morpholine	9.00E+00	guinea pig	mortality	30 days	(WHO, 1996)

COPC	Mammal LOAEL (mg/kg-d)	Test Species	Endpoint	Test Duration	Reference
Cyanide	6.87E+01	rat	reproduction	during gestation and lactation stage	Tewe and Maner, 1980 (cited in (Sample et al., 1996))
Petroleum HydrocarbonF4	N/A	-	-	-	-

Notes:
The TRV for cyanide is a NOAEL. No adverse effects were observed at 500 mg/kg in diet.
The TRV for morpholine is a chronic EC_{20} value, converted from an acute LD_{50} using a factor of 10.
Iron TRV was presented as 3042 mg/kg diet (modified by factoring in body weight of 0.4 kg and food ingestion of 0.24 kg/d from (BC MOE, 1996)).

Table 4.39: Selected Toxicity Reference Values for Birds

COPC	Bird LOAEL (mg/kg-d)	Test Species	Endpoint	Test Duration	Reference
Aluminum	1.10E+02	Ringed Dove	reproduction	4 months	Carriere et al., 1986 (cited in (Sample et al., 1996))
Arsenic	1.28E+01	Mallard	mortality	128 days	USFWS, 1964 (cited in (Sample et al., 1996))
Chlorine (TRC)	nd	-	-	-	-
Copper	6.17E+01	1 day old chicks	growth, mortality	10 weeks	Mehring et al., 1960 (cited in (Sample et al., 1996))
Iron	4.65E+01	chicken	growth	22 days	(Vahl and Van T'Klooster, 1987)
Lead	1.13E+01	Japanese Quail	reproduction	12 weeks	Edens et al., 1976 (cited in (Sample et al., 1996))
Zinc	1.31E+02	White Leghorn Hens	reproduction	44 weeks	Stahl et al., 1990 (cited in (Sample et al., 1996))
Hydrazine	nd	-	-	-	-
Morpholine	nd	-	-	-	-
Cyanide	0.21	American Kestrel	Mortality	-	Weimeyer et al. 1986 (cited in (EC, 1999))
Petroleum Hydrocarbon F4	N/A	-	-	-	-

Notes:
nd = no data available
Cyanide TRV incorporates a safety factor of 10 for acute to chronic.
Iron TRV was presented as 680 mg/kg diet (modified by factoring in body weight of 1.9 kg and food ingestion of 0.13 kg/d from (BC MOE, 1996)).

4.3.2 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 PN assessment of effects on aquatic biota and terrestrial 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 NCRP (NCRP, 1991) and was recommended by the 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 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.

4.3.3 Thermal Benchmarks

Potential thermal effects need to be considered in the context of the type of fish (i.e., warm water or cold water), the life stage of the fish (i.e., spawning, embryo, larval, juvenile or adult), and the type of effect (i.e., chronic or acute). Thermal criteria are typically presented as a maximum weekly average water temperature (MWATs) and/or a short-term daily maximum (STDM) temperature. Hazard quotients (HQ) are then calculated by taking the measured MWAT or STDM at each location, for the seasonal period relevant to each species, and dividing by the MWAT or STDM criterion. Each of the criteria relevant to the PN thermal assessment are described further below. An HQ greater than 1 indicates a need to more closely assess the risk to the concerned VEC.

Other thermal assessment tools are discussed in the evaluation of effects (Section 4.4.3) and are often specific to a species, life stage, season and time of exposure. These include Upper Incipient Lethal (UIL) temperature, Critical Thermal Maximum (CTM), days above a specified temperature, and temperature changes relative to baseline.

Golder (Golder, 2007c) determined maximum weekly average water temperature (MWAT) criteria relevant to fish spawning and embryo-larval development, based on review of thermal effects literature (Wismer and Christie, 1987) and following methods outlined in section 304(a) of the U.S. EPA Clean Water Act. These benchmarks (Table 4.44) represent an upper bound of temperature suitable for embryo and larval development under chronic exposure conditions. Golder (Golder, 2007c) also determined MWAT criteria relevant to growth of juvenile and adult fish (Table 4.48). Criteria were defined for two warm water fish species (Smallmouth Bass and Emerald Shiner) and two cold water species (Round Whitefish and Lake Trout), which were selected as representative species for assessment of thermal effects.

Cooper (Cooper, 2013) considered MWAT criteria and short-term daily maximum (STDM) criteria relevant to fish spawning and embryo-larval development (Table 4.45), as well as MWAT criteria and STDM criteria relevant to growth of juvenile and adult fish (Table 4.49). The STDM criteria represent upper bound temperatures considered suitable for short periods (24 hours). Both criteria were defined for 15 species found in the vicinity of the Pickering station.

Assessment of thermal effects on Round Whitefish embryos is of particular interest as Round Whitefish is considered to be sensitive to elevated water temperatures during the winter months. Lake Whitefish embryos are more tolerant of warmer temperatures than Round Whitefish (i.e., Griffiths (Griffiths, 1980) assumed Round Whitefish spawn at 3.9°C whereas Lake Whitefish were assumed to spawn at 5.8°C). Whitefish have an extended period of egg incubation and embryo development that extends from December into March to mid-April making them susceptible to thermal effects over the incubation period.

For these reasons, OPG (OPG, 2018b, 2020b) assessed the potential effects of the thermal plume on survival of Round Whitefish embryos. The assessment included the use of a thermal survival model to estimate survival loss due to elevated water temperatures in the thermal plume. In addition, the possible effects of short-term periodic increases in water temperature in the thermal plume on Round Whitefish was assessed by comparing the total number of hours that water temperature exceeded 7 or 10°C in the thermal plume and in the reference areas, and the maximum temperature reached at each station during the winter, with the chronic toxicity data for Round Whitefish embryo survival in Griffiths' (1980) study.

4.3.4 Uncertainties in the Effects Assessment

Toxicological benchmarks used in the risk assessment were selected from sources recommended in the CSA N288.6-12 (CSA, 2012), and other reputable sources. These BVs represent the low end of threshold effect levels in literature for each receptor category. BVs for the test species were not adjusted for body weight and were considered directly applicable to the wildlife species. The BVs are considered to be conservatively representative of the effect threshold for the COPC for the receptor of interest. There is uncertainty because most species of interest have not been tested to determine their effect thresholds. Nevertheless, it is expected that few species will be much more sensitive than indicated by the selected benchmark values.

Also, toxicological benchmarks are not available for certain COPCs (e.g., strontium for terrestrial birds and terrestrial plants or tin for soil organisms), therefore no quantitative assessment could be carried out. Without the benchmark value, it is not possible to quantify risk of effects for these biota; however, in these cases a qualitative assessment was carried out.

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 (2008) and CSA N288.6-12 (CSA, 2012) in giving more credence to values based on controlled laboratory studies and demonstrated low levels of effect.

Thermal benchmarks represent a variety of species, life stages and endpoints, and vary among literature sources. Selected values vary among literature sources and have varied somewhat among studies of thermal effects at the Pickering station.

4.4 Risk Characterization

4.4.1 Risk Estimation

Ecological risk is estimated by dividing the exposure value (EV, Section 4.2.5) by the benchmark value (BV, Section 4.3) for a given COPC and receptor species, yielding a hazard quotient (HQ). When the EV for an organism at a site exceeds the BV (HQ > 1), a potential for adverse ecological effects is inferred. A summary of the radiation doses to each receptor by COPC is presented in Table 4.40, and a summary of non-radiological HQs is presented in Table 4.41 through Table 4.43.

Table 4.40: Summary of Radiation Dose Estimates for Biota at the Pickering Site

Location	Receptor	Units	Carbon-14		Cesium-134		Cesium-137		Cobalt-60		Tritium (HTO + OBT)		Iodine-131		Argon-41		Total Dose	
			Max	UCLM	Max	UCLM	Max	UCLM	Max	UCLM	Max	UCLM	Max	UCLM	Max	UCLM	Max	UCLM
Outfall	Benthic Fish	mGy/d	3.96E-05	2.18E-05	2.37E-02	1.47E-03	1.28E-06	6.78E-07	7.75E-07	5.58E-07	2.74E-05	2.43E-06	-	-	-	-	2.38E-02	1.49E-03
	Pelagic Fish	mGy/d	1.43E-05	3.11E-06	1.56E-02	9.61E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.57E-05	1.17E-05	-	-	-	-	1.56E-02	9.76E-04
	Benthic Invertebrate	mGy/d	1.40E-05	3.04E-06	3.82E-02	2.36E-03	0.00E+00	0.00E+00	3.36E-06	2.42E-06	2.58E-05	1.17E-05	-	-	-	-	3.82E-02	2.38E-03
	Ring-Billed Gull	mGy/d	4.43E-03	2.03E-03	2.29E-02	1.44E-03	2.37E-05	2.37E-05	3.97E-05	3.93E-05	5.17E-04	2.16E-04	1.01E-11	1.76E-12	7.05E-05	9.82E-06	2.79E-02	3.76E-03
PN Site	Earthworm	mGy/d	1.81E-04	3.63E-05	2.00E-05	2.00E-05	7.35E-06	7.35E-06	3.14E-05	3.10E-05	5.96E-04	2.47E-04	1.06E-08	1.84E-09	7.05E-05	9.82E-06	9.07E-04	3.52E-04
	Grass/Shrub	mGy/d	2.16E-04	4.33E-05	7.54E-05	7.54E-05	2.86E-05	2.86E-05	1.16E-04	1.12E-04	5.74E-04	2.38E-04	1.02E-07	1.77E-08	7.05E-05	9.82E-06	1.08E-03	5.07E-04
	Pine	mGy/d	2.16E-04	4.33E-05	2.25E-05	2.25E-05	8.14E-06	8.14E-06	3.54E-05	3.40E-05	5.74E-04	2.38E-04	5.77E-09	1.00E-09	7.05E-05	9.82E-06	9.26E-04	3.55E-04
	Red-winged Blackbird	mGy/d	3.68E-04	7.39E-05	3.30E-05	3.16E-05	1.14E-05	1.14E-05	4.78E-05	4.69E-05	3.25E-04	1.35E-04	8.19E-11	1.42E-11	7.05E-05	9.82E-06	8.56E-04	3.08E-04
	Red-tailed Hawk	mGy/d	4.84E-04	9.70E-05	3.34E-05	3.15E-05	1.13E-05	1.13E-05	4.69E-05	4.68E-05	1.85E-04	7.69E-05	2.84E-11	4.92E-12	7.05E-05	9.82E-06	8.30E-04	2.73E-04
	Red Fox	mGy/d	2.95E-03	1.33E-03	3.54E-05	3.41E-05	2.85E-05	2.83E-05	4.54E-05	4.54E-05	3.27E-04	1.36E-04	2.35E-09	4.07E-10	7.05E-05	9.82E-06	3.46E-03	1.58E-03
	Meadow Vole	mGy/d	4.34E-04	8.69E-05	3.18E-05	3.13E-05	1.17E-05	1.17E-05	4.95E-05	4.94E-05	2.51E-04	1.05E-04	1.27E-08	2.20E-09	7.05E-05	9.82E-06	8.48E-04	2.94E-04
	White-tailed Deer	mGy/d	4.34E-04	8.69E-05	2.30E-05	1.66E-05	5.87E-06	5.87E-06	2.63E-05	2.52E-05	2.83E-04	1.18E-04	8.22E-08	1.42E-08	7.05E-05	9.82E-06	8.42E-04	2.62E-04
Frenchman's Bay	White Sucker	mGy/d	1.74E-03	9.15E-04	1.72E-03	1.72E-03	1.55E-03	1.54E-03	3.92E-05	3.23E-05	6.16E-06	4.10E-06	-	-	-	-	5.05E-03	4.21E-03
	Lake Trout	mGy/d	1.74E-03	9.15E-04	1.72E-03	1.72E-03	1.54E-03	1.54E-03	3.06E-05	3.06E-05	6.16E-06	4.10E-06	-	-	-	-	5.03E-03	4.21E-03
	Frog	mGy/d	1.74E-03	9.15E-04	8.10E-04	8.10E-04	1.13E-03	1.12E-03	2.09E-05	1.33E-05	6.16E-06	4.10E-06	-	-	-	-	3.70E-03	2.87E-03
	Aquatic Plant	mGy/d	1.80E-03	9.47E-04	6.44E-05	6.43E-05	8.19E-05	7.59E-05	1.79E-04	1.71E-04	5.95E-06	3.96E-06	-	-	-	-	2.13E-03	1.26E-03
	Benthic Invertebrate	mGy/d	1.70E-03	8.93E-04	3.17E-05	3.10E-05	6.24E-05	3.56E-05	5.40E-05	2.42E-05	6.18E-06	4.11E-06	-	-	-	-	1.85E-03	9.88E-04
	Bufflehead	mGy/d	7.28E-03	3.83E-03	8.87E-05	8.85E-05	8.45E-05	7.55E-05	6.34E-05	5.50E-05	1.11E-05	6.50E-06	1.28E-14	2.23E-15	9.84E-06	3.71E-06	7.54E-03	4.06E-03
	Common Tern	mGy/d	3.51E-03	1.85E-03	2.17E-03	2.17E-03	1.85E-03	1.85E-03	2.68E-05	1.87E-05	7.94E-06	4.41E-06	1.21E-14	2.10E-15	9.84E-06	3.71E-06	7.58E-03	5.90E-03
	Trumpeter Swan	mGy/d	3.51E-03	1.85E-03	1.26E-04	1.26E-04	1.14E-04	1.06E-04	1.80E-04	1.71E-04	7.78E-06	4.30E-06	1.37E-14	2.37E-15	9.84E-06	3.71E-06	3.94E-03	2.26E-03
	Ring-Billed Gull	mGy/d	1.05E-02	5.55E-03	1.34E-03	1.34E-03	1.15E-03	1.14E-03	5.90E-05	5.10E-05	1.55E-05	9.06E-06	1.33E-14	2.31E-15	9.84E-06	3.71E-06	1.31E-02	8.09E-03
	Muskrat	mGy/d	2.89E-03	1.52E-03	7.94E-05	7.92E-05	8.59E-05	7.87E-05	1.66E-05	8.12E-06	7.33E-06	4.19E-06	8.86E-13	1.53E-13	9.84E-06	3.71E-06	3.09E-03	1.70E-03

Notes:
Bold and shaded values exceed the aquatic benchmark of 9.6 mGy/d or the terrestrial benchmark of 2.4 mGy/d.
Max and mean dose for Cobalt-60, Cesium-134, and Cesium-137 are generally equivalent for most receptors since surface water, sediment, and soil concentrations were generally measured below the detection limit.
Iodine-131 and Argon-41 are only applicable to terrestrial and riparian biota.

Table 4.41: Non-Radiological Hazard Quotients for Terrestrial Biota

Receptor	Arsenic		Copper		Lead		Zinc		Cyanide		Petroleum Hydrocarbon F4	
	max	UCLM	max	UCLM	max	UCLM	max	UCLM	max	UCLM	max	UCLM
Earthworm	1.0	0.16	**9.1**	**1.4**	0.46	0.08	**16**	**2.6**	0.04	0.03	**1.7**	**1.1**
Terrestrial Plant	**2.2**	0.37	**8.3**	**1.3**	0.92	0.17	**16**	**2.6**	0.04	0.03	**1.7**	**1.1**
Meadow Vole	0.82	0.14	**2.9**	0.46	0.01	1.9E-03	0.86	0.14	7.5E-06	4.9E-06	nv	nv
Red-winged Blackbird	0.22	0.04	**1.3**	0.20	**1.1**	0.20	**13**	**2.1**	0.02	0.01	nv	nv
Red Fox	0.10	0.03	0.19	0.03	1.8E-03	3.4E-04	0.29	0.05	2.6E-06	1.7E-06	nv	nv
Red-Tailed Hawk	0.27	0.04	0.76	0.12	**1.1**	0.21	**1.6**	0.26	0.09	0.06	nv	nv
White-Tailed Deer	0.39	0.06	**1.4**	0.22	4.6E-03	8.4E-04	0.41	0.07	3.0E-06	2.0E-06	nv	nv

Notes:
Bold and shaded values indicate a HQ > 1
"nv" denotes that HQs were not calculated because COPC is not of toxicological concern to receptor.

Table 4.42: Non-Radiological Hazard Quotients for Aquatic Biota and Riparian Birds and Mammals

Receptors	Hydrazine from CCW		Morpholine from CCW		Morpholine from lake water		Copper		Chlorine (TRC) from CCW		Aluminum		Sodium		Iron	
	max	UCLM	max	UCLM	max	UCLM	max	UCLM	max	UCLM	max	UCLM	max	UCLM	max	UCLM
PN Outfall																
Fish	0.40	0.030	3.3E-04	2.4E-04	7.5E-03	1.6E-04	**2.3**	0.73	**4.1**	**1.7**	N/A	N/A	N/A	N/A	N/A	N/A
Benthic Invertebrate	**6.2**	0.46	6.0E-04	4.4E-04	1.4E-02	2.8E-04	**1.5**	0.46	**7.5**	**3.2**	N/A	N/A	N/A	N/A	N/A	N/A
Ring-billed Gull	nv	nv	nd	nd	nv	nv	0.05	0.01	nv	nv	N/A	N/A	N/A	N/A	N/A	N/A
Frenchman's Bay																
Fish	0.047	0.004	2.2E-04	2.2E-04	8.7E-04	1.8E-05	0.55	0.497	0.47	0.20	0.082	0.062	0.79	0.66	0.43	0.33
Frog (Tadpole)	0.047	0.004	2.2E-04	2.2E-04	8.7E-04	1.8E-05	0.55	0.497	0.47	0.20	0.082	0.062	0.79	0.66	0.43	0.33
Benthic Invertebrate	nd	nd	nd	nd	nd	nd	0.35	0.31	0.87	0.37	0.14	0.11	0.13	0.11	**1.9**	**1.4**
Aquatic Plant (Cattail)	nd	nd	nd	nd	nd	nd	**1.1**	0.95	0.56	0.24	0.59	0.44	0.53	0.44	0.38	0.29
Muskrat	1.49E-03	1.12E-04	4.33E-05	4.33E-05	1.70E-04	3.59E-06	0.14	0.12	8.44E-04	3.61E-04	**5.2**	**3.9**	nv	nv	0.31	0.24
Trumpeter Swan	nv	nv	nv	nv	nv	nv	1.4E-02	1.2E-02	nv	nv	0.38	0.29	nv	nv	**5.2**	**4.0**
Bufflehead	nv	nv	nv	nv	nv	nv	0.016	1.2E-02	nv	nv	**4.1**	**3.1**	nv	nv	**17**	**14**
Common Tern	nv	nv	nv	nv	nv	nv	1.8E-03	1.5E-03	nv	nv	0.20	0.15	nv	nv	**1.0**	0.82
Ring-billed Gull	nv	nv	nv	nv	nv	nv	1.1E-02	9.2E-03	nv	nv	0.66	0.49	nv	nv	**5.2**	**4.0**

Notes:
Bold and shaded values indicate a HQ > 1
"nd" denotes that no data were available
"nv" denotes that parameter not applicable to specific area of assessment
Max and mean HQs for morpholine and TRC are generally equivalent for most receptors since surface water concentrations were generally measured below the detection limit
The HQs for fish, frog, benthic invertebrate, and aquatic plant are based on TRVs for water concentrations
Sodium is considered non-toxic to birds and mammals

Table 4.43: Non-Radiological Hazard Quotients for Benthic Invertebrates from Sediment TRVs

COPC		Benthic Invertebrate	
		PN Outfall	Frenchman's Bay
Copper	**max**	**1.5**	**4.6**
	UCLM	0.3	**3.2**
Iron	**Max**	N/A	2.8E-2
	UCLM	N/A	2.0E-2

Notes:
Bold and shaded values indicate a HQ > 1
N/A denotes that parameter not applicable to specific area of assessment

4.4.2 Discussion of Chemical and Radiation Effects

4.4.2.1 Effects Monitoring Evidence

Data used for the problem formulations, screening and ecological risk assessment were taken from the most recent environmental studies conducted at the PN site. These sources include the 2015 updated baseline environmental monitoring program, previous ERAs, recent monitoring reports from the East Landfill, annual EMP reports, annual compliance reports, the 2007 EA and its associated TSDs. No additional data are available to what is presented at this time to clarify potential effects at the site.

4.4.2.2 Likelihood of Effects

4.4.2.2.1 Atmospheric Contaminants

The maximum POI concentration modelled for sulphur dioxide over the 2016-2020 period was identified in 2016 where the SO_2 concentration at the point of impingement was estimated to be 333 µg/m^3. This 0.5h-hour concentration was adjusted to an annual concentration of 21.6 µg/m^3, exceeding the annual AAQC of 11 µg/m^3 that is protective of vegetation.

Long-term exposures to SO_2 can affect vegetation and ecosystem health through acid rain. Sulphur dioxide penetrates into leaves primarily in gaseous form through the stomata. Acute toxicity can occur in the form of foliar necrosis; although the long-term cumulative exposures are more important and result in reduce growth and yield, and increased senescence (WHO, 2000). However, plants vary in their tolerance to sulphur dioxide and lichens and bryophytes are particularly sensitive. The WHO's annual guideline for sulphur dioxide is an annual average of 30 µg/m^3. These guidelines, which were selected in the mid-1980s but continued to be supported through new experimental data reviewed in 2000, are based on no-effect levels on plants (WHO, 2000).

No significant effects are expected from SO_2 on ecological receptors at the PN site, considering the maximum POI concentration has not exceeded the AAQC for the past four years (see Appendix A, Table A.5), and the highest concentration, adjusted as an annual value, does not exceed no-effect levels (WHO, 2000). Continued monitoring of POI concentrations as part of annual ECA compliance requirements will confirm whether the facility emissions continue to meet the SO_2 vegetation-based AAQC criteria as they have done over the past four years.

4.4.2.2.2 Outfall

Radiological

There are no exceedances of the 9.6 mGy/d radiation benchmark for the aquatic biota at the outfall location including fish and benthic invertebrates. The 2.4 mGy/d radiation benchmark is not exceeded for the Ring-billed Gull.

Non-Radiological

Maximum and UCLM measured concentrations of morpholine in lake water measured near the outfall and in CCW discharges did not exceed their benchmark values for the receptors of interest.

The maximum concentrations of hydrazine, copper and TRC at the outfall exceed the benthic invertebrate benchmark concentration by 1.5 to 7.5 times, thus resulting in a risk (HQ) above 1. Since benthic invertebrates are generally sessile organisms it is expected that a few individuals near the outfall may be exposed to these maximum measured concentrations; however, the benthic community as a whole is not expected to be affected.

The estimated maximum copper concentration in sediment is based on the maximum measured copper concentration in lake surface water with a sediment partition coefficient (K_d) applied; therefore, there is uncertainty around the sediment concentration. Based on UCLM measured copper concentrations near the PN outfall, the estimated sediment concentration is below the sediment benchmark for copper; therefore, effects are not expected for the benthic invertebrate community. Additionally, there is uncertainty surrounding this risk as sediment in Lake Ontario is transient, and the invertebrate community is mainly epifaunal.

The maximum concentrations of copper and TRC exceed the benchmark value for fish by 2.3 and 4.1 times, thus exceeding the acceptable risk level of 1. Based on UCLM concentrations only the benchmark value for TRC was exceeded. Since fish swim around, exposure to the UCLM concentration is more likely and still likely an over-estimate of the exposures of fish that would be unlikely to spend 100% of their time in the outfall. The exposure concentration for TRC is based on discharges at the outfall, and it is expected that concentrations would be rapidly diluted in the lake.

The American Eel is identified as a species at risk; therefore, the assessment endpoint is the health of the individual. As discussed above, the fish benchmark was exceeded in the outfall for maximum measured water concentrations of copper and TRC. Based on UCLM measured water concentrations the fish benchmark was not exceeded for copper but was exceeded for TRC. However, as stated above, the exposure concentration for TRC is based on discharges at the outfall, and it is expected that concentrations would be diluted in the lake. Since fish swim around a wider area, they are also unlikely to be exposed to UCLM concentrations. As such, the American Eel is likely not at risk from PN operations.

4.4.2.2.3 Frenchman's Bay

Radiological

There are no exceedances of the 9.6 mGy/d aquatic radiation benchmark for any aquatic receptors at Frenchman's Bay. There are also no exceedances of the 2.4 mGy/d terrestrial radiation benchmark for birds and mammals at Frenchman's Bay.

Non-Radiological

Maximum and UCLM measured concentrations of hydrazine, morpholine, total residual chlorine, and sodium at Frenchman's Bay did not exceed the benchmark for any of the aquatic biota identified at Frenchman's Bay. For hydrazine, maximum concentrations are based on measured lake water data from 2014 from the vicinity of the PN outfalls (Ecometrix, 2015) with a dilution factor to Frenchman's Bay applied. The hydrazine outfall samples collected in 2014 were considered appropriate for the 2022 ERA since the use of hydrazine at the PN site has not changed between 2014 and the 2016 to 2020 period and hydrazine concentrations in CCW effluent were generally higher in 2014 than during the current ERA period.

There were no toxicity data for hydrazine for birds, as discussed in Section 4.3.1; therefore, risks were not calculated for hydrazine to birds. Hydrazine is not expected to be of concern for birds due to the low risk of food chain bioaccumulation.

The maximum measured copper concentration in water at Frenchman's Bay is 2.1 µg/L, which marginally exceeds the aquatic plant benchmark of 2 µg/L. Measured copper concentrations in water at Frenchman's Bay range from 1.4 to 2.1 µg/L. Based on maximum and UCLM measured copper concentrations in sediment in Frenchman's Bay, the sediment benchmarks were exceeded; therefore, the HQ for benthic invertebrates in Frenchman's Bay exceeded the acceptable risk level of 1. Although the acceptable risk level of 1 for copper was exceeded for benthic invertebrates based on measured sediment concentrations, the contribution from PN operations to the maximum and UCLM copper concentrations in water (and then partitioning to the sediment) at Frenchman's Bay is low and is approximately 8 percent for copper (see Appendix E, Table E.9).

The maximum and UCLM measured iron concentrations in water at Frenchman's Bay exceeded the benthic invertebrate benchmark of 300 µg/L. Although a few benthic invertebrates may be exposed to these maximum measured concentrations, the community as a whole is not expected to be affected. The maximum and UCLM measured iron concentrations in sediment at Frenchman's Bay did not exceed the sediment benchmarks for benthic invertebrates.

The HQs for aluminum for the Muskrat; for aluminum and iron for the Bufflehead, and for iron for the Trumpeter Swan, Common Tern, and Ring-billed Gull exceeded the acceptable risk level of 1. With the exception of the Common Tern, the acceptable risk level of 1 was exceeded for exposures to both the maximum and UCLM measured water and sediment concentrations. Many of these receptors would not reside at Frenchman's Bay exclusively; therefore, the HQs presented are conservative. Additionally, as discussed in Appendix E, exceedances of toxicity benchmarks are not uncharacteristic for an area such as Frenchman's Bay that is highly influenced by urban runoff. PN operations contribute a small proportion of the overall risk to aquatic receptors at Frenchman's Bay. The percent contribution from PN ranges from 0.3% to 22% for most COPCs; the calculated contribution ranges from 17% to 49% for nickel (see Appendix E).

Least Bittern was identified as a species at risk on the PN site; therefore, the assessment endpoint is the health of the individual. The representative species in this ERA is the Common Tern. As discussed above, the HQ for the Common Tern exceeded the acceptable risk level of 1 for maximum concentrations of iron. However, based on UCLM concentrations the HQ for the Common Tern did not exceed the acceptable risk level of 1. Since the Common Tern is mobile, UCLM exposure is more representative than maximum exposure. As such, the Least Bittern (represented by the Common Tern) is likely not at risk from iron exposure in Frenchman's Bay.

4.4.2.2.4 Pickering Nuclear Site

Radiological

There are no exceedances of the 2.4 mGy/d radiation benchmark for terrestrial biota on the PN site including earthworms, terrestrial plants, pine, Meadow Vole, Red-winged Blackbird, Red Fox, and Red-tailed Hawk.

The 2014 ERA concluded that the total radiological dose benchmark was exceeded by the earthworm and Red-winged Blackbird based on the maximum tritium concentration in site soil. The exceedance was based on localized, elevated tritium concentrations in soil close to the reactor buildings. As discussed in Section 4.1.3.3, updated soil data were collected in 2015. To inform the baseline sampling program a site inspection was performed to focus the program on areas with vegetation or organic soil cover. Based on the site inspection, the area near PN U1 and U2 were removed from the soil monitoring program as this is a paved area without suitable habitat for terrestrial receptors. As a result, the dose and risk results for this current ERA provide a more realistic assessment of existing conditions.

Non-Radiological

In general, soils on site that exceed benchmark concentrations are localized, suggesting the influence of past industrial operations rather than deposition from atmospheric sources. As such, COPC accumulation in soil over time is not expected. Instead, the range of concentrations should be reduced as affected areas are identified and cleaned up.

The HQs for copper for the Meadow Vole; for copper, lead and zinc for the Red-winged Blackbird; and for lead and zinc for Red-tailed Hawk, exceeded the acceptable risk level of 1 when exposure to maximum concentrations was assumed. However, these receptors, with the exception of the Meadow Vole which has a small home range, are highly mobile and are unlikely to be exposed to the maximum concentrations for the entire year. The higher HQ value for copper for the Meadow Vole is driven by maximum modelled concentrations in terrestrial plants. The maximum copper concentration in the plant is localized to one sampling location (Site 14 SS5, see Figure 4.9). Therefore, any effects on the Meadow Vole due to copper intake are limited to one area. Although localized effects to individual VECs may occur, the populations on the site as a whole are not expected to be affected.

Based on UCLM concentrations, the HQ for zinc exceeded the acceptable risk level of 1. The higher HQ value for zinc for the Red-winged Blackbird is driven by maximum concentrations in earthworms. Although the Red-winged Blackbird primarily eats insects, for this assessment the earthworm was used as a surrogate for all insects and invertebrates, which is probably conservative since insects have less direct soil contact than earthworms. Additionally, the Red-winged Blackbird is mobile; therefore, exposure to average concentrations in soil is more likely. The HQ based on UCLM concentration was slightly above 1, but such exposure would be limited to one location (Site 14, SS5). Delineation (i.e. sampling 15m on either side of Site 14, SS5) suggests an affected area < 0.07 ha, smaller than one bird's territory. Given the localized nature of the impact and the conservative calculation of zinc uptake into the insect food of the Red-winged Blackbird, it is concluded that Red-winged Blackbirds on site are unlikely to be adversely affected.

Barn Swallow is identified as species at risk; therefore, the assessment endpoint is the health of the individual. The representative species in this ERA is the Red-winged Blackbird. As discussed above, HQs for the Red-winged Blackbird exceeded the acceptable risk level of 1 for maximum concentrations of copper, lead, and zinc in soil. However, based on UCLM concentrations, only the HQ for zinc exceeded the acceptable risk level of 1. Since birds are mobile, mean exposure is more representative than maximum exposure. As such, the Barn Swallow is likely not at risk from PN operations.

Copper (maximum), zinc (maximum and UCLM), and petroleum hydrocarbon F4 (maximum and UCLM) soil exposure concentrations exceeded benchmark values for earthworms. Although localized effects to individual earthworms may occur, the earthworm community on the site as a whole are not expected to be affected.

Maximum soil concentrations of arsenic, copper, zinc, and petroleum hydrocarbon F4 exceeded benchmark values for terrestrial plants. UCLM soil concentrations of zinc also exceeded benchmark values for terrestrial plants. The potential effects on plants due to exposure to arsenic, copper, and petroleum hydrocarbon F4 are expected to be limited to small areas at the PN site. The toxicological benchmarks for these COPCs were exceeded at only 1 out of the 8 sampling locations at the PN site. Arsenic, copper, and petroleum hydrocarbon F4 benchmarks were exceeded at Site 14 SS5 (East Site - ditch north of the east site warehouse, see Figure 4.9). The zinc benchmarks were exceeded at GMS-28, GMS-31, Site 14 SS3 (2 locations), Site 14 SS5 (2 locations), and Site 14 SS6, as shown on Figure 4.9. Although localized effects to individual terrestrial plants may occur, the plant populations on the site as a whole are not expected to be affected.

Butternut is identified as a species at risk; therefore, the assessment endpoint is the health of the individual. The representative species in this ERA is Red Ash (terrestrial plant). While individual plants may be exposed to concentrations above the soil benchmark, there are no trees in these areas of maximum soil concentrations, therefore, Butternut is not at risk in the localized areas of benchmark exceedance.

HQs for exposure of terrestrial mammals and birds to petroleum hydrocarbon F4 were not calculated. Petroleum hydrocarbon F4 is not a toxicological concern for mammals and birds (CCME, 2008).

Pickering Waste Management Facility

The maximum dose rate to any ecological VEC residing in close proximity to the PWMF could be up to 0.012 mGy/d, lower than the 2.4 mGy/d radiation benchmark for terrestrial biota. The dose also remains below the radiation benchmark if the maximum dose from the PWMF is combined with the dose to ecological VECs from being exposed to radionuclides through other existing PN operations (Table 4.40).

4.4.3 Thermal Effects

4.4.3.1 Thermal Plume Effects on Fish Eggs and Larvae

The potential effects of the thermal plume on fish eggs and larvae were evaluated in the Aquatic Environment TSD for the EA for the refurbishment and continued operation of PN Units 5-8 (Golder, 2007c). The thermal regime as influenced by the existing plume was determined by numerical modelling which described the seasonal and spatial variation in water temperature. The modelled MWATs were compared to MWAT criteria representing an upper bound of temperature suitable for fish embryo and larval development under chronic exposure conditions. Similar evaluations of thermal plume effects on fish eggs and larvae were performed by Cooper using measured MWATs and STDMs from temperature dataloggers compared to MWAT criteria and STDM criteria (Cooper, 2013). Results from both studies are presented in this section.

For Round Whitefish, a thermal survival model has been used to assess the potential effects of the thermal plume on embryo survival, and a threshold of 7°C has been used to evaluate for acute effects on Round Whitefish embryos (OPG, 2018b, 2020b) . The evaluation of embryo-larval development for Round Whitefish is presented in Section 4.4.3.1.1. Thermal effects on growth of juvenile and adult fish are considered in Section 4.4.3.2.

The MWAT criteria from Golder (Golder, 2007c) for embryo and larval development, for Smallmouth Bass, Emerald Shiner and Lake Trout, are shown in Table 4.44. These criteria are calculated from an optimum temperature and an upper lethal temperature, as per the section 304(a) of the U.S. EPA Clean Water Act. They are applicable during the relevant timeframe for embryo-larval development.

Table 4.44: Thermal Criteria Relevant to Embryo and Larval Development of Selected Fish Species (Golder, 2007c)

Fish Species	Life Stage	Optimum Temp (°C)	Upper Lethal Temp (°C)	MWAT Criteria (°C)	Relevant Timeframe
Smallmouth Bass	Embryo	18	37	24.3	mid-Apr-May
	Larvae	21	33	25	mid-Apr-May
Emerald Shiner	Embryo	24	29	27	mid-Apr-May
	Larvae	24	29	27	mid-Apr-May
Lake Trout	Embryo	-	14.8	10	December
	Larvae	-	14.8	10	Dec- Apr

The cold water species (Round Whitefish and Lake Trout) spawn on shoals and rocky substrates located in the shallow nearshore waters east of the PN generating station. Lake Trout spawn in December. The larval periods for both species extend into April.

Among the warm water species, Smallmouth Bass spawn primarily within the intake and discharge channels, which are the primary local habitat for all life stages. The Emerald Shiner prefers nearshore areas with substrate structure. Spawning and embryo-larval development occurs primarily around the armoured break wall and intake channel and may also include portions of the discharge channel. The spawning and larval periods for both species extend from mid-April through May, although Emerald Shiner may spawn through August.

Golder (Table A3.1-1, Golder, 2007c) found that modelled MWATs for Smallmouth Bass, Round Whitefish, Emerald Shiner and Lake Trout did not exceed MWAT criteria for spawning and larval development in any areas of suitable spawning habitat during the relevant timeframe. In April-June, only the discharge channels had modelled values marginally above MWAT criteria (i.e., at 27°C). In the winter period, relevant to Lake Trout, modelled values above MWAT criteria were found in the discharge channels, and at one lake location (N) near the PN U5-8 discharge with modelled values as high as 12°C; these locations do not represent Lake Trout habitat. Therefore, it was concluded that temperatures in the thermal plume are unlikely to have adverse effects on fish embryo-larval development.

In the discharge channel, OPG measures the temperatures continuously, and this information can be used to understand the degree and frequency with which MWAT criteria are exceeded. The rolling 7-day average temperatures from PN U5-8 were calculated from the instantaneous daily maximum effluent temperatures between 2016-2020 (OPG, 2017j, 2018k, 2019f, 2020g, 2021h), and those exceeding MWAT criteria for Smallmouth Bass and Emerald Shiner of 24.3°C and 27°C were counted. There were no occurrences in 5 years over the April-May embryo-larval period where the 7-day average exceeded MWAT criteria for the embryo-larval period for the Emerald Shiner, and one occurrence over the five years where the 7-day average exceeded MWAT criteria for the embryo-larval period for Smallmouth Bass. Therefore, the temperature of the PN U5-8 discharge is not expected to cause detrimental effects to reproductive performance the Emerald Shiner. The duration of the exceedance for the Smallmouth Bass was 4 days and occurred at the end of May in 2020. The highest annual 7-day averages over the embryo-larval period from 2016-2020 ranged from 21.5 to 25.3°C. These exceedances are not considered detrimental to reproductive performance because they occur rarely, and late in the embryo-larval life stages, and are localized to the discharge channel (0.0062 km^2). While this area is considered to be spawning habitat for Smallmouth Bass, the nearshore area outside of the channel is used by the Emerald Shiner.

Cooper (2013) evaluated lake temperatures in the vicinity of the PN U5-8 discharge using 2011-2012 data provided by OPG from thermal dataloggers placed on the substrate. Temperature results at locations in the thermal plume and in reference areas (Thickson Point and Bonnie Brae Point, 20 km east and 26 km east of Pickering Nuclear, respectively), were compared to thermal criteria for 15 species and HQ values were calculated for relevant time periods for each species at each location. The thermal criteria relevant to fish embryo-larval periods are listed in Table 4.45 for nine species that are VECs in the ERA.

Table 4.45: Thermal Criteria Relevant to Spawning and Embryo-Larval Development of VECs in the EcoRA (Cooper, 2013)

Species	Maximum Weekly Average Temperature (MWAT) (°C)			Short-Term Daily Maximum Temperature (STDM) (°C)		
	Spawning	Egg	Larvae	Spawning	Egg	Larvae
American Eel	18.2	-	-	-	31.7	31.2
Brown Bullhead	22.5	-	-	-	26	-
Round Whitefish	3	4.6	4.6	-	6.3	-
White Sucker	10	-	28	24.1	24.1	30
Emerald Shiner	23.5	-	-	-	27	-
Lake Trout	9	-	-	-	10	-
Northern Pike	11.5	-	-	-	20.9	26.9
Smallmouth Bass	17	-	-	-	28.3	-
Walleye	8.5	-	-	-	20	-

Hazard quotients were calculated by taking the measured MWAT or STDM at each location, for the seasonal period relevant to each species, and dividing by the MWAT or STDM criterion. Table 4.46 presents the HQ values for the species considered in the assessment and identified as VECs for the EcoRA. Five had HQ values at least marginally above 1, indicative of potential adverse effects from the thermal plume. The HQ is shown for the highest temperature location in the plume area, and in the reference area. The HQs in the plume area are not substantially elevated relative to the reference area. Lake Trout had embryo-larval HQs marginally above 1, but the HQs for reference areas were also above 1, and those in the plume area were only slightly higher.

Table 4.46: Thermal Hazard Quotients Relevant to Spawning and Embryo-Larval Development of Selected Fish Species in Lake Ontario near the PN U5-8 Discharge (Cooper, 2013)

Species	PN U5-8						Reference Locations (Bonnie Brae and Thickson Point)					
	HQ_{MWAT}			HQ_{STDM}			HQ_{MWAT}			HQ_{STDM}		
	Spawning	Egg	Larvae	Spawning	Egg	Larvae	Spawning	Egg	Larvae	Spawning	Egg	Larvae
American Eel	Not calculated						Not calculated					
Brown Bullhead	0.82	-	-	-	0.73	-	Not calculated					
Round Whitefish	2.83	1.91	1.93	-	1.62	-	2, 1.97	1.74, 1.76	1.78, 1.76	-	1.43, 1.38	-
White Sucker	1.69	-	0.81	0.79	0.9	0.8	1.93, 1.87	-	0.81, 0.80	0.86, 0.82	0.92, 0.89	0.8, 0.79
Emerald Shiner	Not calculated						Not calculated					
Lake Trout	2.33	-	-	-	1.28	-	2.33, 2.31	-	-	-	1.06, 1.04	-
Northern Pike	nr	-	-	-	0.85	0.66	nr	-	-	-	0.87, 0.86	0.68, 0.67
Smallmouth Bass	1.08	-	-	-	0.67	-	1.14, 1.10	-	-	-	0.73, 0.70	-
Walleye	1.05	-	-	-	0.89	-	0.96, 0.69	-	-	-	0.91, 0.90	-

Notes:

Shaded identifies a hazard quotient >1

4.4.3.1.1 Thermal Increments and Embryo-larval Survival of Round Whitefish

Temperature is considered the main factor affecting hatching time and spawning success for Round Whitefish, and it has therefore been identified as a species of interest to assess thermal emissions from PNGS. Round whitefish spawn nearshore on coarse substrate in late fall with eggs hatching in early spring. Egg survival over winter is thought to be potentially affected by elevated discharge plume temperature.

Water temperature on the Round Whitefish spawning beds has been monitored by OPG using dataloggers installed over the 2009-2010, 2010-2011 and 2011-2012 embryo-larval incubation periods (OPG, 2010b, 2012b, 2013a).

OPG evaluated the potential effect of lake water temperature in the thermal plume at PN and reference sites on the survival of Round Whitefish using the 2009-2010, 2010-2011 and 2011-2012 temperature data and a thermal survival model (OPG, 2018b). The thermal survival model used a revised Hybrid Block 1 Model and the COG Block 3 Model, where Block 1 refers to the early incubation period of Round Whitefish embryos, and Block 3 refers to the late incubation period. As shown in Table 4.47, the estimated survival loss at the plume stations compared to the reference stations (Thickson Point and Bonnie Brae) was low: 0.80% in 2009-2010, 1.39% in 2010-2011, and 2.51% in 2011-2012. These values are all below the threshold no-effect level of 10% for survival loss of Round Whitefish embryos. However, in 2011-2012, a year with warmer winter water temperatures, the threshold no-effect level of 10% relative survival loss was exceeded at one station, P1 (10.76%).

Following this evaluation, two years of additional monitoring were completed over the periods December 2018 to April 2019, and December 2019 to April 2020 by OPG (OPG, 2020b). Plume bottom temperature loggers were deployed at 16 locations near the U5-8 discharge and to the east of Duffins Creek, 0.51km and 2.07 km from the discharge point, respectively. Seven reference loggers were also deployed at Bonnie Brae Point. Deployment depth ranged from 4m to 12m. The largest relative survival loss observed was 3.8% in 2018-2019 and 1.5% in 2019-2020, at plume locations closest to the PNGS B discharge channel. These values are well below the CNSC threshold of concern of 10% relative survival loss. Therefore, the more recent studies continue to support that there is no chronic adverse effect on round whitefish egg survival.

Table 4.47: Predicted Round Whitefish Egg Survival based on the Revised Hybrid Model and Winter Temperature Data at Reference and Plume Stations (OPG, 2018b, 2020b)

2009-2010						
	Block 1		Block 3		Block 1 + 3	
	Ref.	Plume	Ref.	Plume	Ref.	Plume
Mean Temperature (°C)	2.28	3.45	4.06	4.18	-	-
Hatch Dates	-	-	25-Mar-10 to 29-Mar-10	12-Mar-10 to 23-Mar-10	-	-
Embryo survival	99.10%	98.36%	98.70%	98.64%	97.81%	97.03%
Relative survival loss	0.75%		0.06%		0.80%	
2010-2011						
	Block 1		Block 3		Block 1 + 3	
	Ref.	Plume	Ref.	Plume	Ref.	Plume
Mean Temperature (°C)	3.26	4.22	1.88	2.68	-	-
Hatch Dates	-	-	17-Mar-11 to 22-Mar-11	24-Feb-11 to 11-Mar-11	-	-
Embryo survival	98.58%	97.35%	99.26%	99.12%	97.86%	96.50%
Relative survival loss	1.25%		0.14%		1.39%	
2011-2012						
	Block 1		Block 3		Block 1 + 3	
	Ref.	Plume	Ref.	Plume	Ref.	Plume
Mean Temperature (°C)	4.67	5.20	3.18	3.94	-	-
Hatch Dates	-	-	1-Mar-12 to 6-Mar-12	16-Feb-12 to 2-Mar-12	-	-
Embryo survival	96.45%	94.29%	99.02%	98.71%	95.47%	93.07%
Relative survival loss	2.24%		0.31%		2.51%	
2018-2019						
	Block 1		Block 3		Block 1 + 3	
	Ref.	Plume	Ref.	Plume	Ref.	Plume
Mean Temperature (°C)	2.57	4.00	2.64	2.93	-	-
Hatch Dates	-	-	3-Apr-19 to 6-Apr-19	11-Mar-19 to 28-Mar-19	-	-
Embryo survival	99.0%	97.7%	99.1%	99.1%	98.0%	96.8%
Relative survival loss	1.30%		0.0%		1.3%	
2019-2020						
	Block 1		Block 3		Block 1 + 3	
	Ref.	Plume	Ref.	Plume	Ref.	Plume
Mean Temperature (°C)	2.79	3.73	3.31	3.78	-	-
Hatch Dates	-	-	25-Mar-20 to 28-Mar-20	10-Mar-20 to 19-Mar-20	-	-
Embryo survival	98.8%	98.1%	99%	98.8%	97.8%	96.9%
Relative survival loss	0.7%		0.2%		0.9%	

Notes:
Block 1 is the early incubation period of Round Whitefish embryos, 31 days post-fertilization. Fertilization was assumed to be December 1 prior to 2018, and December 15 in 2018-2020.
Block 3 is the late incubation period of Round Whitefish embryos, 31 days prior to median hatch (based on degree days).

As mentioned by OPG (OPG, 2018b), acute threshold temperatures for Round Whitefish embryos are not available. The Upper Incipient Lethal (UIL) test, defines an acute thermal threshold as the temperature resulting in 50% mortality in a 7-day exposure (Wismer and Christie, 1987). Further, investigation of the potential effects of short term temperature increases revealed that acute effects are unlikely (OPG, 2018b). Although not designed to develop an acute threshold, Griffiths data shows that continuous exposure at 7°C does not result in acute mortality in either Block 1 (75% survival after 17 days) or Block 3 (56% survival after 30 days) (Griffiths, 1980). In addition, continuous exposure at 10°C does result in low survival both in Block 1 (11% survival after 13 days) and Block 3 (0% survival after 9 days). However, it should be noted that this temperature condition (i.e. continuous exposure at 10°C) does not exist in the actual plume as the longest duration is limited to periods of 7 hours (above 10°C only for 1 hour at P6 in 2010-2011, for 7 hours at P1, and 1 hour at P2 and 1 hour at P6 in 2011-2012 over the winter period, with a maximum 1 hour temperature reaching 11.39°C at Station P1 on December 15, 2011).

Griffiths (1980) also tested other temperature regimes where temperature was maintained at one temperature for 18 hours and cycled to another temperature for 6 hours. This temperature cycling was continued for a number of days and the percent survival recorded. For example, repeated 6-hour exposure to 10°C, from a base level of 7°C, in the Griffiths study, did increase mortality (50% survival after 17 days in Block 1 and 16% survival after 30 days in Block 3).

It is recognized that there are limitations to interpreting the available data from Griffiths (1980) with respect to an acute threshold and the experimental test regimes do not necessarily reflect the behavior of the thermal plume but it can be postulated that 50% mortality could potentially occur between 7°C and 10°C provided that the exposure time is of sufficient duration. Nevertheless, although the acute threshold may be in this temperature range, the duration of exposure above 7°C in the plume is not long enough to result in an acute response.

OPG has chosen a conservative value of 7°C for plume temperature at which there could be a possible indication of acute temperature effects. Between December 2018 and March 2019, eight locations had hourly temperatures exceeding 7°C, with the longest consecutive period above 7°C being 13 hours. Between December 2019 and March 2020, seven locations had hourly temperatures exceeding 7°C, with the longest consecutive period being 26 hours. These short-term exceedances of temperatures above 7°C are believed to have no adverse effects on the development of Round Whitefish embryos (OPG, 2020b).

4.4.3.2 Thermal Plume Effects on Growth of Juveniles and Adults

The potential effects of the thermal plume on fish growth were evaluated in the Aquatic Environment TSD for the EA for the refurbishment and continued operation of the PN Units 5-8 (Golder, 2007c). The thermal regime as influenced by the existing plume was determined by numerical modelling which described the seasonal and spatial variation in water temperature. The modelled MWATs were compared to MWAT criteria representing an upper bound of temperature suitable for growth under chronic exposure conditions. MWAT criteria were defined for two warm water fish species (Smallmouth Bass and Emerald Shiner) and two cold water species (Round Whitefish and Lake Trout) (Golder, 2007c, Table A2.5-1). These species were selected based on local abundance and identified potential for thermal plume effects. While some other fish species (White Sucker, Walleye, Northern Pike) are common in the area, they are transient or do not have susceptible life history stages. The MWAT criteria for juveniles and adults are considered here (Table 4.50). Thermal effects on spawning and embryo-larval development are considered in Section 4.4.3.1.

Table 4.48: Thermal Criteria Relevant to Growth and Mortality of Selected Fish Species (Golder, 2007b)

Fish Species	Life Stage	Optimum Temp (°C)	Upper Lethal Temp (°C)	MWAT Criteria (°C)	Nearshore Timeframe
Smallmouth Bass	Adult	21	36	29, 33	all year
	Juvenile	28.5	35	29	all year
Round Whitefish	Adult	15	26.7	18.9	mid-Nov-Dec
	Juvenile	17, 18.5	26.7	20.2, 21.2	mid-Nov-Dec
Emerald Shiner	Adult	25	42	30	all year
	Juvenile	23	35	30	all year
Lake Trout	Adult	12	21.5	19.4	mid-Nov-Apr
	Juvenile	12	21.5	19.4	mid-Nov-Apr

The cold-water species avoid the Lake Ontario nearshore during the summer period, and are thus not exposed to the thermal plume at this time. For example, Round Whitefish are potentially exposed from mid-November to early December and Lake Trout are potentially exposed from mid-November to April. Golder (Golder, 2007c) found that modelled MWATs did not exceed criteria for growth of juveniles and adults of Round Whitefish and Lake Trout at the time that they are present in the nearshore area.

The warm water species are potentially exposed to the thermal plume during the summer growth period when ambient and discharge water temperatures are highest. The discharge and intake channels have been identified as the primary habitat areas for the Smallmouth Bass in the area. The modelled MWATs marginally exceeded the criteria for growth of juveniles and adults occasionally at one lake location near the PN U5-8 discharge over the July to September period (e.g., up to 29.93°C vs criterion of 29°C for Smallmouth Bass) and only in the near surface water. Deeper water at the same location did not exceed the criterion. Residing mainly near the bottom, these fish would likely not be exposed to temperatures that are adverse for growth.

In the discharge channel, OPG measured the temperatures continuously over the 2016 to 2020 period in order to better understand the degree and frequency with which MWAT criteria are exceeded. As part of this effort, the MWAT criteria for growth were reviewed. The two values given by Wismer and Christie (1987) for Smallmouth Bass are 29°C for juveniles (from U.S. EPA, 1974) and 32-33 °C for juveniles and adults (from Wrenn, 1980). The U.S. EPA value was calculated using an optimum growth temperature of 26°C and an upper lethal temperature of 35°C, both attributed to a lab study by Horning and Pearson (1973). However, the cited study does not provide an upper lethal temperature. The Wrenn value was calculated by the author using an optimum growth temperature of 30°C and an upper lethal temperature of 37°C, both based on a field study involving a series of outdoor channels heated to specified thermal increments by passing the water through the heat exchangers at a nuclear power plant. OPG has used a growth MWAT of 32°C from Wrenn (1980), because its derivation is transparent, and because its variable thermal regime is realistic and directly relevant to the situation in PN discharge channels.

In analyzing the 2016-2020 PN U5-8 discharge temperatures (OPG, 2017j, 2018k, 2019f, 2020g, 2021h), the rolling 7-day average temperatures were calculated, and those exceeding MWAT criteria for Smallmouth Bass and Emerald Shiner were counted. There were 18 occurrences in 5 years when the 7-day average exceeded the 30°C MWAT criterion for Emerald Shiner (2-5 events/year), with an average duration of 16 days. There were 15 occurrences when the 7-day average exceeded the 32°C MWAT criterion for Smallmouth Bass, with an average event duration of 10 days. The highest 7-day average value was 36.1°C. These exceedances are not considered detrimental for growth of Smallmouth Bass or Emerald Shiner because they are small and occasional (as described) and localized to the discharge channel (0.0062km^2). Fish are able to optimize temperature by movement in and out of the discharge channel. Optimum temperature for growth is reported to be 27-29°C for Emerald Shiner (Wismer and Christie, 1987) and 29-30°C for Smallmouth Bass (Wrenn, 1980).

Potential for lethality due to short-term elevations in temperature is usually evaluated by comparison of short-term average temperatures to the Upper Incipient Lethal (UIL) temperature, or the CTM temperature. The upper lethal values in Table 4.48 are UIL values. These criteria, from Wismer and Christie (1987), are based on abrupt transfer of fish to a range of higher temperatures, for a 7-day duration. Fish may survive these temperatures for shorter exposure times.

The 7-day average maximum daily temperatures in the discharge channel exceeded 35°C 11 times in 2016 and 8 times in 2018; none in 2017, 2019 or 2020 (OPG, 2017j, 2018k, 2019f, 2020g, 2021h). The 1-day maximum temperature exceeded 35°C between 2 to 15 times per year over the 2016-2020 timeframe. Based on this comparison, conditions for thermal lethality were likely encountered during the 2016-2020 period within the discharge channel. As stated earlier, these short-term exceedances are likely localized to the discharge channel.

The CTM criterion can also be used as a benchmark for acute lethality. This criterion is based on exposure to an increasing temperature, with rate of increase less than 1°C per hour. The CTM is the temperature at which loss of equilibrium or muscle spasms occur. The rate of increase is fast enough that fish do not have time to acclimate over the course of the test. Consequently, CTM varies with the initial acclimation temperature. CTM criteria of 36.9°C and 34.8°C have been reported for juvenile and adult Smallmouth Bass, respectively, at acclimation temperatures of 26°C and 10°C, respectively (Beitinger et al., 2000; EPRI, 2011). CTM criteria of 37.6°C and 34.1°C have been reported for juvenile Emerald Shiners at acclimation temperatures of 25°C and 10°C, respectively (Beitinger et al., 2000). The higher acclimation temperatures are appropriate for the summer period. These higher CTM values of 37°C for Smallmouth Bass and 38°C for Emerald

Shiner may be compared to hourly average temperatures over the summer period. Review of the hourly average effluent temperature data from July to October indicates that a temperature of 37°C was exceeded for a total of 36 hours over the 2011-2015 timeframe. These data were not reported for the 2016-2020 timeframe.

No fish kills have been observed during the high temperature excursions. Fish are likely able to avoid the rare excursions when they need to by moving in and out of the discharge channel.

Algal growth events during the late summer and fall occasionally require the cooling water intake pumps to be shut off to clear the algae, which results in a slightly increased discharge temperature. Hourly temperature values for influent and effluent, and ΔT values, are routinely monitored, and daily average values are calculated for comparison to the ECA ΔT limit of $^{+}11^{\circ}$C. Based on results over the 2016 to 2020 period, only PN U5-8 experienced algae events with ΔT limit exceedance. In 2016, there were twelve algae events, and eight of those events exceeded the daily average ΔT limit (OPG, 2017j). As discussed previously in Section 4.1.3.11.2, the number of algal events decreased to only 1 or 2 events after the acquisition of an algae harvester in 2017 and development of the AAWS in 2019 to forecast future algae run events. During these events, effluent temperature has usually increased by a few degrees, and the daily average temperature has occasionally exceeded the MWAT criterion for Smallmouth Bass (29°C). Weekly average temperatures during these events generally do not exceed the criterion.

In summary, algal events have the potential to slightly increase water temperatures in the discharge channel, and water temperatures near the surface in the lake near the discharge, for short periods of time. These brief and occasional changes in thermal regime due to algal events would not be expected to have any substantial effect on the suitability of nearshore waters for growth of the fish species that reside there at the time of these events.

As discussed in Section 4.4.3.1, Cooper (2013) evaluated lake temperatures in the vicinity of the PN U5-8 discharge using 2011-2012 data provided by OPG from thermal dataloggers placed on the substrate. Temperature results at locations in the thermal plume and in reference areas (Thickson Point and Bonnie Brae Point) were compared to thermal criteria for 15 fish species and HQ values were calculated for relevant time periods for each species at each location. The thermal criteria relevant to juvenile and adult stages are listed in Table 4.49 for eight species that are VECs in the ERA.

Table 4.49: Thermal Criteria Relevant to Juvenile and Adult Stages of Selected Fish Species (Cooper, 2013)

Species	Maximum Weekly Average Temperature (MWAT) (°C)		Short-Term Daily Maximum Temperature (STDM) (°C)	
	Juvenile	Adult	Juvenile	Adult
American Eel	-	-	-	-
Brown Bullhead	32	-	37	37.8
Round Whitefish	-	-	-	-
White Sucker	28	28	35.6	31.6
Emerald Shiner	30	30	34.3	-
Lake Trout	19.4	-	21.5	23.5
Northern Pike	26.4	28	33.3	30
Smallmouth Bass	32.5	31	35	32
Walleye	25	25	28.5	-

HQs were calculated by taking the measured MWAT or STDM at the most exposed plume location, for the seasonal period relevant to each species, and dividing by the MWAT or STDM criterion. The most exposed location in 2011-2012 was station P1 which was nearest the PN U5-8 discharge, at a distance of approximately 200 m (Cooper, 2013). The 7-day rolling average temperature at station P1 did not exceed 23°C.

Table 4.50 presents the HQ values for juvenile and adult stages for the selected species. The HQ is shown for the highest temperature location in the plume area, and in the reference area. The highest HQs were marginally above 1 in the plume for Lake Trout but were less than or equal to reference values for this species. Therefore, it is unlikely that there are any effects arising from the thermal plume in the lake for juvenile or adult stages of any fish species.

Overall, exceedances of thermal criteria relevant to growth of juveniles and adults are confined to the discharge channel, where criteria for Smallmouth Bass and Emerald Shiner are exceeded by a few degrees, occasionally and for short periods. The fish using the discharge likely benefit by optimizing temperature for growth. There would be no adverse effect on the larger populations.

Table 4.50: Thermal Hazard Quotients Relevant to Juveniles and Adults of Selected Fish Species in Lake Ontario near the PN U5-8 Discharge (Cooper, 2013)

Species	PN U5-8				Reference Locations (Bonnie Brae and Thickson Point)			
	HQ_{MWAT}		HQ_{STDM}		HQ_{MWAT}		HQ_{STDM}	
	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult
American Eel	Not calculated				Not calculated			
Brown Bullhead	0.7	-	0.65	0.63	Not calculated			
Round Whitefish	Not calculated				Not calculated			
White Sucker	0.81	0.81	0.67	0.76	0.81, 0.80	0.81, 0.80	0.67, 0.67	0.76, 0.75
Emerald Shiner	Not calculated				Not calculated			
Lake Trout	1.16	-	1.11	1.02	1.17, 1.16	-	1.11, 1.11	1.02, 1.02
Northern Pike	0.85	0.81	0.72	0.8	0.86, 0.85	0.81, 0.80	0.72, 0.71	0.80, 0.79
Smallmouth Bass	0.69	0.73	0.68	0.75	0.70, 0.69	0.73, 0.73	0.68, 0.68	0.75, 0.74
Walleye	0.9	0.9	0.84	-	0.91, 0.90	0.91, 0.90	0.84, 0.84	-

4.4.3.3 Thermal Plume Contribution to Winter Cold Shock

Cold shock in fish can occur as a result of natural changes in water temperature, or cold shock can be induced by either reduction in temperature when the number of operating units declines, or when fish pass through the thermal plume and encounter a high thermal gradient between ambient and plume conditions. For example, during an outage, thermal additions to receiving water can be rapidly curtailed, such that water temperature in the plume decline more rapidly than fish are able to acclimate to lower temperatures (Coutant, 1977). Water temperature may fall below the lower lethal temperature, and fish mortality due to cold shock may occur. Unless induced by natural events, cold shock is likely to occur only during a full station outage. A full station outage is a rare event and usually only occurs every 10 years when a vacuum building outage is required; however, vacuum building outages are planned and units can be derated over a period of time to avoid drastic temperature reductions in the plume that could result in acute effects.

OPG is currently evaluating the potential for natural and operationally induced cold shock at PN and are in discussion with DFO on this topic. The discussions are presently focused on Alewife and Gizzard Shad since these species are fragile to cold temperatures and may become more prone to impingement if affected by naturally or operationally induced cold shock death or morbidity, and having to offset for impingement losses outside of OPG's operational control is a liability to the company.

4.4.4 Entrainment/Impingement

Fish impingement sampling was conducted at PN from September 2003 to September 2004. Fish egg/larvae entrainment sampling was conducted from mid-March through December 2006. These results were evaluated in 2007 and 2008 in terms population-relevant metrics, comparable to fishery statistics, as recommended in CSA N288.6-12. Subsequently, in October 2008, OPG was ordered by the CNSC to reduce fish impingement at the Pickering station by 80%, and to reduce fish entrainment by 60%, relative to the baseline year (2003/04). In order to reduce impingement, OPG installed a fish diversion system (FDS), in October 2009. The approved rate of entrainment during operations phase is 106 kg age 1 equivalent (A1E) per year based on the values provided in the 2017 PNGS Fisheries Act Application for Authorization. This entrainment estimate is 1.7 % of the 6143 kg A1E per year estimated impingement during operations. No reasonable technological solution is available to reduce entrainment by 60% (OPG, 2012a), but both impingement and entrainment losses are required to be counterbalanced by the three offset measures that were approved by DFO in the PN Fisheries Act Authorization. The offset measures consist of a portion of the Big Island Wetland Fish Habitat Bank, a portion of the restored Simcoe Point Wetland, and 2018-2020 stocking contributions of Lake Ontario Atlantic Salmon into Duffins Creek. Offset monitoring field studies are to be conducted and reports are to be submitted to DFO as conditions of the Authorization, and demonstrating the offset measures effectively counterbalance the impingement and entrainment residual impacts and risks.

A *Fisheries Act* Authorization for PN operational activities was issued to OPG by Fisheries and Oceans Canada (DFO) on January 17, 2018, associated with the continual intake of cooling water from Lake Ontario. An annual impingement monitoring report is submitted to DFO to satisfy conditions of the Authorization. The DFO Authorization included a 2-year biomass condition, where consultation with DFO is required if the combined biomass across all species and ages is over 3,619 kg/yr in two consecutive years (OPG, 2020c).

Table 4.51 summarizes the recent results from 2016 to 2020 (OPG, 2017d, 2018f, 2019c, 2020c, 2021f). In 2017, the total biomass of all species and ages impinged was 25,217 kg, which is equivalent to a rate of 4.99 kg/$Mm^3$of station flow. The results in 2017 were heavily influenced by a single event starting on November 16 and lasting several days, which was reported to CNSC and DFO. During the event, a preliminary estimate of 24,000 kg of Alewife were impinged. In the absence of this event, impingement was 1,217 kg, the second lowest on record since assessment commenced in 2010 (OPG, 2018f).

Fish impingement in 2018 and 2019 were higher than recorded in the prior five years but each year was influenced by outliers in the weekly impingement data which affected monthly extrapolations of all-ages impingement, and subsequent Age-1 equivalent estimates (OPG, 2020c). Subsequent investigation of the factors contributing to the 2018 and 2019 impingement (Patrick, 2020) determined that elevated values were primarily attributed to unusually cold weather, rapid water temperature decreases (observed at the intake, within and/or outside of the plume) and other environmental phenomena.

OPG and DFO are currently discussing the 2018-2019 impingement rates, and factors contributing to impingement that are within or beyond OPG's operational control. Until such time that those discussions are complete, impingement estimates for 2018-2020 are considered preliminary. Age-1 equivalent estimates for 2017-2020 have been submitted to DFO and are currently under DFO review. The Age-1 equivalent estimates submitted may be revised subject to the approval of all-ages impingement estimates, and/or to the modification of Age-1 equivalent life history data for certain species.

Table 4.51: Impinged Biomass in 2016-2020 (OPG, 2017d, 2018f, 2019c, 2020c, 2021f)

Fish Species	2016 (kg)	2017 (kg)	2018 (kg)	2019 (kg)	2020 (kg)
Freshwater Drum	10	0.3	15.9	1.4	48.8
Brown Bullhead	18	8.0	12.1	27.7	9.6
Alewife	139	218	4,270	11,194	337
Carp	39	96	78	172	86.8
Gizzard Shad	274	377	819	2,708	2,031
Salmonids	24.0	0	0	10.3	0
Walleye	0	0.05	0	16.5	21.9
White Sucker	19	24	20.9	21.9	8.1
Threespine Stickleback	1.0	13	9.5	61.0	37.7
Emerald Shiner	2.0	1.0	1.7	1.7	24.2
Smallmouth Bass	3.0	30	4.5	9.7	4.3
Northern Pike	31	21	106	143	99.2
Rainbow Smelt	25	38	21.6	27.0	56.1
American Eel	104	200	49.8	58.8	90.5
Yellow Perch	4.0	11	10.1	2.8	13.3
Sea Lamprey	5.0	3.0	10.3	0	1.3
Round Goby	85	113	94.7	451	226
Other Species	252	63.7	91.9	208	430
Total Biomass (kg)	**1,035**	**1,217**	**5,616**	**15,115**	**3,526**
Annual Impingement Rate (kg/Mm^3)	**0.22**	**0.24**	**1.15**	**2.87**	**0.72**

In 2016, biomass lost to impingement was reduced by 88% relative to baseline, meeting or exceeding the 80% reduction target. As discussed previously a high level of impingement was observed in 2017 due to a fish impingement event that was reported to CNSC and DFO; However, in the absence of this event impingement in 2017 was one of the lowest impingement years on record.

Impingement trends over the 2018-2020 period are compared against the 3,619 kg two-year threshold as per Condition 3.2.1.1. of the *Fisheries Act* authorization. Impingement estimates provided in 2018-2019 indicate an exceedance of the two-year threshold, and DFO was notified. Further evaluation by Patrick (2020) concluded that the exceedances did not appear to be caused by PNGS operations. In 2020, impingement estimates were less than 3,619 kg, and therefore impingement was below the two-year threshold.

4.4.4.1 Northern Pike

The loss of Northern Pike has not been reduced overall by the FDS, likely because this species is prevalent in the winter when the FDS is not in place.

OPG has participated with the TRCA in tagging Northern Pike captured in the Pickering area nearshore, Frenchman's Bay and Duffins Creek Marsh (OPG, 2017d). During impingement monitoring, Northern Pike are scanned to determine if the fish contain a tagging device. Over the 2010 – 2020 period, only one tagged individual has been confirmed as impinged since monitoring of tags began in 2010. No tagged individuals were reported over the 2016-2020 period. This result suggests that impinged pike represent a small fraction of the local population, consistent with the Golder (Golder, 2007c) finding (Section 4.4.4.1) that impinged pike represent a small fraction of the commercial harvest in the Canadian waters of Lake Ontario.

4.4.4.2 American Eel

The American Eel is listed as endangered under Ontario's Endangered Species Act (ESA). It declined through the 1980s to a low point in the late 1990s. It has recovered slightly since then, with implementation of fish passage programs, and with closure of all commercial and recreational fishing in Ontario in 2004.

American Eel impinged by the cooling water system have been documented and reported under an ESA permit issued to OPG issued previously by the Ministry of Natural Resources and Forestry, Lake Ontario Management Unit. Jurisdiction over the ESA changed in 2019 and ESA is now the mandate of the Ministry of Environment, Conservation and Parks (MECP).

Adult American Eel of stocked or wild origin are impinged by PNGS and numbers tracked and reported to CNSC, DFO, MNRF and MECP. From 2010-2020, American Eel impinged annually ranges from 16-112 individuals and 0.5 – 104 kg reported biomass impinged. These are estimated numbers based on captures in weekly impingement monitoring, as opposed to actual observations. These estimates are sensitive to small increases in the number of individual American Eel captured during weekly bin collections since the process of expanding the data from sample days to the total intake volume for the month assumes the species is present proportional to the counts on the sampled days. On occasion, live American Eel are observed in a traveling screen or bar screen bin and are returned to the lake.

PNGS voluntarily retains American Eel and sends them for subsequent internal examination to determine sex, origin (wild or stocked), and whether natural parasites are present or not. In 2021, OPG submitted an Application for an Overall Benefit Permit for American Eel to MECP, and

MECP is presently reviewing the application. To offset American Eel impingement at PNGS, OPG has proposed to continue American Eel impingement monitoring, and to supplement the existing spring and fall trap and transport program implemented as part of the OPG Action Plan for Offsetting Turbine Mortality of American Eel at the R.H. Saunders Generating Station and Agreement under the Endangered Species Act, 2007, O. Reg. 242/08, Section 11.

4.4.5 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 4.2.6), as well as benchmarks values used to determine risk of potential effects (uncertainties discussed in Section 4.3.4).

Beta and gamma emissions from PN are measured as a gross value, rather than by individual radionuclide. In the ecological risk assessment, cesium-134 was used as the limiting radionuclide representing gross beta-gamma activity for waterborne discharges from the PN outfall, consistent with the HHRA. Cesium-134 was selected after comparing the relative contributions of Cs-134, Cs-137 and Co-60 to radiological dose for ecological receptors specific to the PN ERA. Cesium-134 is the limiting radionuclide for exposures to water, but cobalt-60 is the limiting radionuclide for receptors with sediment exposures such as benthic invertebrates, riparian birds and fish, as explained in Appendix C. As shown in Table C-3 for benthic invertebrates, for an equal activity mixture of the three radionuclides in water, the percentage of resulting total dose attributed to cobalt-60 is 83%, when exposed to equal concentrations of cobalt-60, cesium-134 and cesium-137, or just under 5 times higher. Therefore, it is considered possible that the predicted doses to benthic invertebrates, and some riparian birds, and bottom-feeding fish may be associated with waterborne emissions up to five times higher using a Co-60 surrogate as compared to Cs-134. However, even with a five-times adjustment factor, the doses are still well below aquatic and terrestrial dose benchmarks.

The risk characterization for the Red-winged Blackbird indicated HQ>1 based on UCLM soil concentrations. The soil sampling on the PN Site was biased to areas of potential soil contamination. Thus, both mean and UCLM concentrations are likely over-estimates of the actual exposure in a Red-winged Blackbird's territory. Moreover, a single location of high concentration (Site 14, SS5) inflates the standard deviation and the UCLM for zinc in soil. Delineation (i.e. sampling 15m on either side of Site 14, SS5) suggests an affected area < 0.07 ha, smaller than one bird's territory. Without this high value, the upper bound HQ is below 1.

The risk characterization for thermal effects on Round Whitefish is based on models fitted to the most current scientific data. These models treat exposure in early (Block 1) and late (Block 3) stages of embryo development as separate chronic effects. Although there is a theoretical potential for latent temperature effects experienced in Block 1 to be realized in Block 3, no existing models (COG, 2013; Gagnon, 2011; Griffiths, 1980) can account for this. Results of both the Griffiths and COG study show that mortality at temperatures actually measured in the plume is low. MNRF studies indicate that Round Whitefish is a lake wide population (Wood et al., 2016). Therefore, the risk of the plume to a lake wide population is negligible. As such, additional refinement of the model is not warranted.

Overall, considering uncertainties in the exposure assessments and the benchmark values, it is reasonable to consider that HQs above 1 for a COPC, receptor and location are indicative of a potential for adverse effects. However, it does not necessarily imply adverse effects. The interpretation of HQ results also takes into consideration the distribution of areas with HQ>1, the mobility and home range of the affected receptor, and whether the exposure point concentrations can be attributed to PN operations.

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.

5.0 Conclusions and Recommendations

5.1 Conclusions

5.1.1 Conclusions of Human Health Risk Assessment (HHRA)

5.1.1.1 Non-Radiological HHRA

The COPCs assessed in the non-radiological HHRA included NO_x in air and hydrazine in water and fish. Potential risks to human receptors were characterized quantitatively in terms of Hazard Quotients (HQs) for NO_x inhalation and Incremental Lifetime Cancer Risks (ILCRs) for hydrazine, which is a potential carcinogen.

The conclusions of the quantitative HHRA are as follows:

- The target for non-cancer risk was not exceeded for any potential critical group based on modelled annual average air concentrations for nitrogen oxides. However, a potential short-term exposure risk was identified for the Sport Fisher, for which short-term exposures exceed the acceptable hazard quotient. Since other potential critical groups are farther away, it is anticipated that the hazard quotient for the other receptors will be lower than that for the Sport Fisher.

- Risk to human receptors via drinking water is considered to be unlikely. The incremental lifetime cancer risk for hydrazine in drinking water was less than the acceptable cancer risk level of 10^{-6} for the Urban Resident and Correctional Institution resident based on the upper confidence limit of the mean (UCLM) concentrations of hydrazine in the CCW discharge. Risks were calculated incorporating the understanding that hydrazine is known to degrade rapidly under chlorinated conditions typically used for treatment/distribution of drinking water (EC and HC, 2011). A dilution factor of 42 was used to estimate intake concentrations at the Ajax Water Supply Plant based on Condenser Cooling Water (CCW) discharge concentrations (EC and HC, 2011).

- The incremental lifetime cancer risk to the Sport Fisher from ingestion of fish containing hydrazine is based on the conservative assumption that 100% of the fish in the Sport Fisher's diet is obtained from fish collected in the vicinity of PNGS. Risk to the Sport Fisher to hydrazine via fish ingestion was calculated using either measured nearfield lake water concentrations at the outfall or CCW discharge concentrations. Fish tissue concentrations were calculated using an uptake factor and an applied dilution factor of 4.2 to estimate intake water concentrations at the Sport Fisher location, 500 metres offshore. Based on measured lake water concentrations at the outfall, exposure to the UCLM hydrazine concentration for the Sport Fisher through fish ingestion is below the acceptable cancer risk level of 10^{-6}. Since fish are mobile, exposure to the UCLM hydrazine concentration is more realistic than exposure to the maximum concentration. Using the UCLM hydrazine concentrations measured in the CCW discharge to estimate risk, the incremental lifetime cancer risk due to fish ingestion by the Sport Fisher exceeded the acceptable level by 6.7 times. Realistically, a fisher would likely visit and harvest fish from various locations throughout the year including those unaffected by PN emissions.

5.1.1.2 Radiological HHRA

For exposure of human receptors to radiological COPCs, the relevant exposure pathways and human receptors (potential critical groups) were those presented in the annual OPG EMP reports. Radiological dose calculations followed the methodology outlined in CSA N288.1-14 (CSA, 2014) and N288.1-20 (CSA, 2020). Table 3.19 presents a summary of the maximum critical group dose from 2016 to 2020. The annual dose during this five-year period ranged from 1.2 to 2.1 µSv and the critical group was the Urban Resident (adult). The dominant pathways and radionuclides contributing to the total dose are inhalation of tritium and external exposure to noble gases.

Over the five-year period (2016-2020), the public dose estimates for the critical group (Urban Resident) are approximately 0.2% of the regulatory public dose limit of 1 mSv/a and approximately 0.1% to 0.15% of the Canadian background radiation. Since the critical group receives the highest dose from PN, the demonstration that they are protected implies that other receptor groups near PN, and those farther away, are also protected.

The Sport Fisher may receive a maximum dose up to 0.063 µSv/a from exposure to the PWMF (Phase I and Phase II) when it is at full capacity, adjusted for occupancy from the maximum dose presented in the PWMF Safety Report (OPG, 2018a). The dose to the Sport Fisher from existing PN operations ranges from 0.2 to 0.5 µSv/a; therefore, the total dose from PN operations and the PWMF may be up to 0.5065 µSv/a; however, this is still a small fraction of the regulatory public dose limit.

Facility releases are considered to be adequately controlled, and further optimization of PN operations is not required. Nevertheless, the ALARA principle is applied at PN to reduce emissions as much as is reasonably achievable.

Since the dose estimates are a small fraction of the regulatory public dose limit, and of natural background exposure, no discernable health effects are anticipated due to exposure of potential critical groups to radioactive releases from PN.

5.1.1.3 Noise Effects

The Acoustic Assessment Report (OPG, 2011a) prepared for PN demonstrates that PN operates in compliance with applicable regulatory noise limits. The 2011 Acoustic Assessment Report was subsequently reviewed and approved by the MECP. In issuing the ECA for PN (OPG, 2016d), the MECP verified that the findings of the Acoustic Assessment Report adequately demonstrate that PN does not cause a substantial noise impact at the identified PORs.

Although there are periods of recorded maximum sound levels above the MECP NPC 300 Class 1 and Class 2 sound level limits, based on site observations these are unlikely to be directly associated with PN activities. These elevated sound levels are likely the result of localized events such as road traffic or human activity in the vicinity of the noise monitoring locations. It is common for noise levels in populated urban areas, such as near the PN site, to occasionally exceed the applicable prescribed sound level limit. As these occasional periods of elevated sound levels are not likely associated with PN activities, it is not expected that noise from PN activities is having a direct adverse effect on human receptors near the PN site.

5.1.2 Results of Ecological Risk Assessment (EcoRA)

5.1.2.1 Non-Radiological EcoRA

The potential for ecological effects was assessed by comparing exposure levels to toxicological benchmarks, and characterized quantitatively in terms of Hazard Quotients (HQs). An HQ greater than 1 indicates a need to more closely assess the risk to the concerned VEC.

PN Site- Atmospheric Contaminants

No significant adverse effects are expected from sulphur dioxide (SO_2) to ecological receptors at the PN site. Elevated concentrations of sulphur dioxide were predicted to be released in 2016 (based on 2015 ESDM modelling), resulting in an exceedance of the annual AAQC concentration that is protective of vegetation. However, considering that the maximum predicted point of impingement (POI) concentration for SO_2 has not exceeded the AAQC for the past four years (see Appendix A, Table A.5), and the highest concentration, adjusted as an annual value, does not exceed no-effect levels (WHO, 2000), no long-term adverse effects to vegetation are expected based on current emission rates. Continued monitoring of POI concentrations as part of annual ECA compliance requirements will confirm whether the facility emissions continue to meet the SO_2 vegetation-based AAQC criteria as they have done over the past four years.

Outfall

Maximum and UCLM measured concentrations of morpholine in lake water measured near the outfall and in CCW discharges did not exceed their benchmark values for the receptors of interest.

The benthic invertebrate community is not expected to be affected by the maximum concentrations of hydrazine, copper and TRC at the outfall. Water concentrations exceeded the benthic invertebrate benchmark concentration by 1.5 to 7.5 times, resulting in an HQ above 1. While benthic invertebrates are generally sessile organisms it is expected that a few individuals near the outfall may be exposed to these maximum measured concentrations; however, the benthic community as a whole is not expected to be affected.

Effects are not expected for the benthic invertebrate community due to copper exposure in sediment, since the estimated sediment concentration (UCLM) near the PN outfall is below the sediment benchmark for copper. There is uncertainty surrounding this risk as estimated maximum copper concentration in sediment is based on the maximum measured copper concentration in lake surface water with a sediment partition coefficient (K_d) applied, sediment in Lake Ontario is transient, and the invertebrate community is mainly epifaunal.

Although the maximum concentrations of copper and TRC at the outfall exceeded the benchmark value for fish by 2.3 and 4.1 times, effects on fish are unlikely. Based on UCLM concentrations only the benchmark value for TRC was exceeded. Since fish swim around, exposure to the UCLM concentration is more realistic, and still likely an over-estimate of the exposures of fish, since they would be unlikely to spend 100% of their time in the outfall. The exposure concentration for TRC is based on discharges at the outfall, and it is expected that concentrations would be rapidly diluted in the lake.

The American Eel is identified as a species at risk; therefore, the assessment endpoint is the health of the individual. The American Eel is likely not at risk from PN operations. As discussed above, the fish benchmark was exceeded in the outfall for UCLM measured water concentration of TRC. However, as stated above, the exposure concentration for TRC is based on discharge measurements, and it is expected that concentrations would be diluted in the lake. Further, since fish swim around a wider area, they are also unlikely to be exposed to UCLM concentrations.

Overall, the risk to fish at the outfall is low, and fish are not expected to experience any adverse effects due to chemical releases from PN operations.

Frenchman's Bay

Maximum and UCLM measured concentrations of hydrazine, morpholine, total residual chlorine, and sodium at Frenchman's Bay did not exceed the benchmark for any of the aquatic biota identified at Frenchman's Bay. For hydrazine, maximum concentrations are based on measured lake water data from 2014 near the PN outfalls (Ecometrix, 2015) with a dilution factor to Frenchman's Bay applied.

There were no toxicity data for hydrazine for birds, as discussed in Section 4.3.1; therefore, risks were not calculated for hydrazine to birds. Hydrazine is not expected to be of concern for birds due to the low risk of food chain bioaccumulation.

Aquatic plants and the benthic invertebrate community are not expected to be at risk at Frenchman's Bay, and the overall contribution from PN operations to the risk is low. Although the maximum measured copper concentration in water at Frenchman's Bay is 2.1 µg/L, which marginally exceeds the aquatic plant benchmark of 2 µg/L. the UCLM measured copper concentration in water at Frenchman's Bay is below the aquatic plant benchmark. Measured copper concentrations in water at Frenchman's Bay range from 1.4 to 2.1 µg/L. Based on maximum and UCLM measured copper concentrations in sediment at Frenchman's Bay, the sediment benchmark was exceeded; therefore, the HQ for benthic invertebrates in Frenchman's Bay exceeded the acceptable risk level of 1. Although a few benthic invertebrates may be exposed to the maximum measured concentration of copper in sediment, the community as a whole is not expected to be affected. Additionally, although the acceptable risk level of 1 for copper was exceeded for benthic invertebrates based on measured sediment concentrations, the contribution from PN operations to the maximum and UCLM copper concentrations in water (and then partitioning to the sediment) at Frenchman's Bay is low and is approximately 8 percent for copper (see Appendix E, Table E.9).

Although a few benthic invertebrates may be exposed to the maximum measured iron concentrations in water, the community as a whole is not expected to be affected. The maximum and UCLM measured iron concentrations in water at Frenchman's Bay exceeded the benthic invertebrate benchmark of 300 µg/L. The maximum and UCLM measured iron concentrations in sediment at Frenchman's Bay did not exceed the sediment benchmarks for benthic invertebrates.

The HQs for aluminum for the Muskrat; for aluminum and iron for the Bufflehead, and for iron for the Trumpeter Swan, Common Tern, and Ring-billed Gull exceeded the acceptable risk level of 1. With the exception of the Common Tern, the acceptable risk level of 1 was exceeded for exposures to both the maximum and UCLM measured water and sediment concentrations. Many of these receptors would not reside at Frenchman's Bay exclusively; therefore, the HQs presented are conservative. Additionally, as discussed in Appendix E, exceedances of toxicity benchmarks are not uncharacteristic for an area such as Frenchman's Bay that is highly influenced by urban runoff. PN operations contribute a small proportion of the overall risk to aquatic receptors at Frenchman's Bay. The percent contribution from PN ranges from 0.3% to 22% for most COPCs; the calculated contribution ranges from 17% to 49% for nickel (see Appendix E).

Least Bittern was identified as a species at risk on the PN site; therefore, the assessment endpoint is the health of the individual. The representative species in this ERA is the Common Tern. As discussed above, the HQ for the Common Tern exceeded the acceptable risk level of 1 for maximum concentrations of iron. However, based on UCLM concentrations, the HQ for the Common Tern did not exceed the acceptable risk level of 1. Since the Common Tern is mobile, UCLM exposure is more representative than maximum exposure. As such, the Least Bittern (represented by the Common Tern) is likely not at risk from iron exposure in Frenchman's Bay.

Pickering Nuclear Site

In general, soils on site that exceed benchmark concentrations are localized, suggesting the influence of past industrial operations rather than deposition from atmospheric sources. As such, COPC accumulation in soil over time is not expected. The soil sampling program focused on areas of previously identified contamination. Although soil sampling only occurred in areas identified as potential habitat, many of these areas on the PN site are not likely to be frequented by the selected VECs since they are near PN operations and not in highly vegetated areas.

The HQs for copper for the Meadow Vole; for copper, lead and zinc for the Red-winged Blackbird; and for lead and zinc for Red-tailed Hawk, exceeded the acceptable risk level of 1 when exposure to maximum concentrations was assumed. However, these receptors, with the exception of the Meadow Vole which has a small home range, are highly mobile and are unlikely to be exposed to the maximum concentrations for the entire year. The higher HQ value for copper for the Meadow Vole is driven by maximum modelled concentrations in terrestrial plants. The maximum copper concentration in the plant is localized to one sampling location (Site 14 SS5, see Figure 4.9). Therefore, any effects on the Meadow Vole due to copper intake are limited to one area. Although localized effects to individual VECs may occur, the populations on the site as a whole are not expected to be affected.

When exposed to UCLM concentrations, the HQ for zinc exceeded the acceptable risk level of 1 for the Red-winged Blackbird. The higher HQ value for zinc for the Red-winged Blackbird is driven by maximum concentrations in earthworms. Although the Red-winged Blackbird primarily eats insects, for this assessment the earthworm was used as a surrogate for all insects and invertebrates, which is conservative. Additionally, the Red-winged Blackbird is mobile; therefore, exposure to average concentrations in soil directly or indirectly through ingestion of prey is more likely. The HQ for zinc based on UCLM concentration was slightly above 1, but such exposure would be limited to one location (Site 14, SS5). Given the localized nature of the impact and the conservative calculation of zinc uptake into the insect food of the Red-winged Blackbird, it is concluded that Red-winged Blackbirds on site are unlikely to be adversely affected.

Barn Swallow is identified as a species at risk; therefore, the assessment endpoint is the health of the individual. The representative species in this ERA is the Red-winged Blackbird. As discussed above, HQs for the Red-winged Blackbird exceeded the acceptable risk level of 1 for maximum concentrations of copper, lead, and zinc in soil. However, based on UCLM concentrations, only the HQ for zinc exceeded the acceptable risk level of 1. Since birds are mobile, UCLM exposure is more representative than maximum exposure. As such, the Barn Swallow is likely not at risk from PN operations.

Copper (maximum), zinc (maximum and UCLM), and petroleum hydrocarbon F4 (maximum and UCLM) soil exposure concentrations exceeded benchmark values for earthworms. Although localized effects to individual earthworms may occur, the earthworm community on the site as a whole is not expected to be affected.

Maximum soil concentrations of arsenic, copper, zinc, and petroleum hydrocarbon F4 exceeded benchmark values for terrestrial plants. UCLM soil concentrations of zinc also exceeded benchmark values for terrestrial plants. The potential effects on plants due to exposure to arsenic, copper, and petroleum hydrocarbon F4 are expected to be limited to small areas at the PN site. The toxicological benchmarks for these COPCs were exceeded at only 1 out of the 8 sampling locations at the PN site. Arsenic, copper, and petroleum hydrocarbon F4 benchmarks were exceeded at Site 14 SS5 (East Site - ditch north of the east site warehouse, see Figure 4.9). The zinc benchmarks were exceeded at GMS-28, GMS-31, Site 14 SS3 (2 locations), Site 14 SS5 (2 locations), and Site 14 SS6, as shown on Figure 4.9. Although localized effects to individual terrestrial plants may occur, the plant populations on the site as a whole are not expected to be affected.

Butternut is identified as a species at risk; therefore, the assessment endpoint is the health of the individual. The representative species in this ERA is Red Ash (terrestrial plant). While individual plants may be exposed to concentrations above the soil benchmark, there are no trees in these areas of maximum soil concentrations, therefore, Butternut is not at risk from the localized areas of benchmark exceedance.

HQs for exposure of terrestrial mammals and birds to petroleum hydrocarbon F4 were not calculated. Petroleum hydrocarbon F4 is not a toxicological concern for mammals and birds (CCME, 2008).

5.1.2.2 Radiological EcoRA

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 biota, respectively, as recommended in the CSA N288.6-12 standard (CSA, 2012).

Outfall

There were no exceedances of the radiation dose benchmarks for the aquatic or riparian biota at the outfall location including fish, benthic invertebrates, and Ring-billed Gull.

Frenchman's Bay

There were no exceedances of the radiation dose benchmarks for any aquatic or riparian receptors at Frenchman's Bay.

Pickering Nuclear Site

There were no exceedances of the radiation dose benchmark for terrestrial biota on the PN site including earthworms, terrestrial plants, Meadow Vole, Red-winged Blackbird, Red Fox, Red-tailed Hawk and White-tailed Deer.

The 2014 ERA concluded that the total radiological dose benchmark was exceeded by the earthworm and Red-winged Blackbird based on the maximum tritium concentration in site soil. The exceedance was based on localized, elevated tritium concentrations in soil close to the reactor buildings. As discussed in Section 4.1.3.3, updated soil data were collected in 2015. To inform the baseline sampling program a site inspection was performed to focus the program on areas with vegetation or organic soil cover. Based on the site inspection, the area near PN U1 and U2 was removed from the soil monitoring program as this is a paved area without suitable habitat for terrestrial receptors. As a result, the dose and risk results for this current ERA provide a more realistic assessment of existing conditions.

Pickering Waste Management Facility

The maximum dose rate to any ecological VEC residing in close proximity to the PWMF could be up to 0.012 mGy/d; lower than the 2.4 mGy/d radiation benchmark for terrestrial biota. The dose also remains below the radiation benchmark if the maximum dose from the PWMF is combined with the dose to ecological VECs from being exposed to radionuclides through other existing PN operations.

5.1.2.3 Physical Stressors

Thermal stressors, entrainment and impingement were the relevant physical stressors evaluated in the EcoRA since they are widely recognized as being of primary concern in nuclear power plants, as recommended by CSA N288.6-12 (CSA, 2012).

Thermal Effects

Cooper (2013) evaluated lake temperatures in the vicinity of the PN U5-8 discharge using 2011-2012 data provided by OPG from thermal dataloggers placed on the substrate. Temperature results at locations in the thermal plume and in reference areas (Thickson Point and Bonnie Brae Point) were compared to thermal criteria and HQ values were calculated for relevant time periods for each species at each location. Thermal criteria relevant to spawning and embryo-larval periods, and juvenile and adult stages were presented for weekly and daily averaging periods (MWAT and STDM criteria). An HQ above 1 is indicative of potential adverse effects from the thermal plume. HQs were presented for the highest temperature location in the plume area, and in the reference area. For fish spawning and embryo-larval development, the highest HQs were marginally above 1 in the plume, but usually very similar in the reference areas.

OPG (2020b) evaluated the effect of lake water temperature from the thermal plume at PN on Round Whitefish embryo survival for the winters of 2018-2019 and 2019-2020 using a thermal survival model. The model used a revised Hybrid Block 1 Model and the COG Block 3 Model, where Block 1 refers to the early incubation period of Round Whitefish embryos and Block 3 refers to late incubation period. The estimated survival losses at the plume stations compared to the reference stations (Thickson Point and Bonnie Brae) was 1.3% in 2018-2019, and 0.9% in 2019-2020. These values for survival loss are all below a survival loss of 10%, the recommended threshold for no-effect on Round Whitefish embryo survival. Therefore, the thermal plume from PN is not having an effect on Round Whitefish embryo survival.

OPG has chosen a conservative value of 7°C for plume temperature at which there could be a possible indication of acute temperature effects. Between December 2018 and March 2019, eight locations had hourly temperatures exceeding 7°C, with the longest consecutive period above 7°C being 13 hours. Between December 2019 and March 2020, seven locations had hourly temperatures exceeding 7°C, with the longest consecutive period being 26 hours. These short-term exceedances of temperatures above 7°C are believed to have no adverse effects on the development of Round Whitefish embryos.

For fish growth (juvenile and adult), the highest HQs calculated by Cooper (2013) were marginally above 1 in the plume for Lake Trout, but were less than or equal to reference values for this species. Therefore, it is unlikely that there are any effects arising from the thermal plume in the lake for juvenile or adult stages of any fish species.

Within the discharge channel, Smallmouth Bass and Emerald Shiner are occasionally exposed to temperatures that exceed their thermal criteria relevant to fish growth. These events are of short duration and never more than a few degrees above criteria. They are localized to the discharge channel and would have no adverse effect on the larger fish populations. The fish using the discharge channel likely benefit by optimizing temperature for growth over the summer period.

Cold shock in fish can occur as a result of natural changes in water temperature, or cold shock can be induced by either reduction in temperature when the number of operating units declines, or when fish pass through the thermal plume and encounter a high thermal gradient between ambient and plume conditions. OPG is currently evaluating the potential for natural and operationally induced cold shock at PN and are in discussion with DFO on this topic.

Entrainment and Impingement

In October 2008, OPG was ordered by the CNSC to reduce fish impingement at the Pickering station by 80%, and to reduce fish entrainment by 60%, relative to the baseline year (2003/04). In order to reduce impingement, OPG installed a barrier net in October 2009. No reasonable technological solution is available to reduce entrainment by 60% (OPG, 2012a), but these losses are offset by OPG participation in the Bring Back the Salmon Program (Lake Ontario Atlantic Salmon Restoration Program, 2011).

A *Fisheries Act* Authorization for PN operational activities was issued to OPG by DFO on January 17, 2018, associated with the continual intake of cooling water from Lake Ontario. An annual impingement monitoring report is submitted to DFO to satisfy conditions of the Authorization. The *Fisheries Act* Authorization included 2-year biomass condition, where consultation with DFO is required if the combined biomass across all species and ages is over 3,619 kg/yr in two consecutive years (OPG, 2020c).

In 2016, biomass lost to impingement was reduced by 88% relative to baseline, meeting or exceeding the 80% reduction target. As discussed previously, a high level of impingement was observed in 2017 due to a fish impingement event that was reported to CNSC and DFO; however, in the absence of this event impingement in 2017 was one of the lowest impingement years on record.

Impingement trends over the 2018-2020 period are compared against the 3,619 kg two-year threshold as per Condition 3.2.1.1. of the *Fisheries Act* authorization. Impingement estimates provided in 2018-2019 indicate an exceedance of the two-year threshold, and DFO was notified. Further evaluation by Patrick (2020) concluded that the exceedances did not appear to be caused by PNGS operations. In 2020, impingement estimates were less than 3,619 kg, and therefore impingement was below the two-year threshold.

5.2 Recommendations for the Monitoring Program

If radiation or chemical doses are predicted to exceed benchmarks and the exceedances are reasonably expected to be facility related, it is recommended that OPG confirm exposure conditions, and proceed either to monitor for the effects relevant to benchmark exceedances, or to evaluate options for risk management if the need for risk management is clear. The confirmation of exposure may involve refinement of exposure estimates from existing data, or obtaining new monitoring data where exposures were based on predicted concentrations.

In order to clarify risk in future human and ecological assessments, the following specific recommendations for monitoring or desktop studies are provided:

- To reduce uncertainty regarding the short-term nitrogen oxide concentrations at the locations of the Sport Fisher and other potential critical groups, it is recommended that future air dispersion modelling scenarios include estimation of the predicted air concentrations at the potential critical group receptor locations. Currently, the point of impingement concentrations at the property boundary have been assumed for the Sport Fisher, but it is unclear whether this concentration is appropriate to assess the short-term inhalation risks at their location, 500 m off shore. These refined predicted concentrations can then be used to refine the short-term risk estimates for all potential critical group locations in the ERA.

- Following the 2017 ERA, ECCC recommended that future ERA iterations use existing habitat information to estimate the percentage of warmwater fish habitat (i.e., Emerald Shiner, Smallmouth Bass) that could be affected by the discharge. The merits and limitations of this recommendation were discussed in a January 31, 2022 meeting between OPG, ECCC and CNSC. It was agreed by all parties that the limitations outweighed the benefits and, therefore, no further analysis by OPG would be conducted.

- Although site soil data from 2015 confirms localized areas of contamination (Site 14 SS3, SS5, SS6, GMS-28, and GMS-31, as shown on Figure 4.9), no specific monitoring or remediation is recommended at this stage as the contamination will be addressed during decommissioning of the PN site. According to the preliminary decommissioning plan for the PN site all contamination exceeding the established clearance levels for a 'brown field' site will be removed from the site or remediated on site in order to restore the site to a state suitable for other OPG uses; clearance levels will be developed prior to decommissioning (OPG, 2016a).

- Consistent with the requirements of CSA N288.6-12 clause 11.1 to periodically review changes to the facility, the expansion of PWMF Phase II will likely result in changes to the stormwater catchments in the East Complex. The appropriate stormwater outfalls in the East Complex should be reviewed and sampled accordingly to be representative of the catchment areas after the completion of PWMF Phase II expansion. Included in this study should be consideration of the catchment areas 11, 12, and 14-16A as shown in Figure 3.5. At the present time, further stormwater sampling has been postponed until the

PWMF Phase II expansion is further along. Gross beta-gamma in stormwater was monitored and reported quarterly over the 2016-2020 period; however, in 2021 OPG determined that no routine monitoring is required given the robust design of the used fuel dry storage containers (DSCs) and absence of liquid inside the DSCs during dry storage (OPG, 2021b). Following their review of the 2017 ERA, CNSC and ECCC recommended that a stormwater sampling plan be included in future ERA submissions. OPG plans to carry out this recommendation prior to and for inclusion in the 2027 ERA.

- It is recommended that OPG continue to engage with local Indigenous communities to develop ongoing and meaningful dialogue, and in particular, to engage prior to/during the preparation of the next ERA to incorporate Indigenous Knowledge and/or perspectives, as available. It is recommended that future ERAs include a section in the report that discusses what was heard from the engagement activities and how this feedback has been considered in the assessment.

5.3 Risk Management Recommendations

No risk management recommendations are made at this time.

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Appendix A Screening Tables Used for the HHRA and EcoRA

Table A.1: Non-Radiological Screening of Air COPCs for Human Health

Contaminant	CAS No.	Averaging Period	Maximum POI Concentration (µg/m³)						Screening Criteria				Carried Forward as COPC for the HHRA?
			2016[b]	2017[c]	2018[d]	2019[e]	2020[f]	2016-2020 Maximum	Selected Value (µg/m³)	Source / Basis	O. Reg. 419/05 Schedule Number[a]	Limiting Effect	
2-(2-aminoethoxy) ethanol	929-06-6	0.5hr	0.549	0.49	-	-	-	0.549	57	MECP POI Limit	Sch. 2	Health	No
		24hr	-	-	0.11	0.11	0.12	0.12	19	MECP POI Limit	SL-JSL	Health	
Acetic Acid	64-19-7	0.5hr	3.33	2.5	-	-	-	3.33	250	TCEQ Short-Term ESL	--	Health	No
Acetone	67-64-1	0.5hr	0.335	-	-	-	-	0.335	35640	MECP POI Limit	Sch. 2	Health	No
Ammonia	7664-41-7	0.5hr	212	172	-	-	-	212	300	MECP POI Limit	Sch. 2	Health	No
		24hr	-	-	8	8	9	9	100	MECP POI Limit	Sch. 3	Health	
Ammonium Hydroxide	1336-21-6	0.5hr	0.0213	-	-	-	-	0.0213	180	TCEQ Short-Term ESL	--	Health	No
Amyl Alcohol	71-41-0	0.5hr	0.00107	-	-	-	-	0.00107	73	TCEQ Short-Term ESL (annual)	--	Health	No
Benzo(a)pyrene	50-32-8	0.5hr	-	0.00013	-	-	-	0.00013	0.00015	MECP POI Limit	Sch. 2	Health	No
		24hr	-	-	0.000026	0.000026	0.000029	0.000029	0.005	MECP POI Limit	Sch. 6	URT	
		Annual	-	-	0.00000056	0.00000056	0.00000047	0.00000056	0.00001	MECP POI Limit	Sch. 3	Health	
Cadmium	7440-43-9	0.5hr	-	0.00081	-	-	-	0.00081	0.075	MECP POI Limit	Sch. 2	Health	No
Carbon dioxide	124-38-9	0.5hr	-	32123	-	-	-	32123	767400	MECP POI Limit	Sch. 2	Health	No
		24hr	-	-	12268	12268	13598	13598	255800	MECP POI Limit	SL-PA	Health	
Carbon monoxide	630-08-0	0.5hr	145	-	-	-	-	145	6000	MECP POI Limit	Sch. 2	Health	No
Chromium VI	7440-47-3VI	0.5hr	-	0.00051	-	-	-	0.00051	0.0021	MECP POI Limit	Sch. 2	Health	No
		24hr	-	-	0.00011	0.00011	0.00012	0.00012	0.07	MECP POI Limit	Sch. 6	URT	
		Annual	-	-	0.0000017	0.0000017	0.0000015	0.0000017	0.00014	MECP POI Limit	Sch. 3	Health	
Cobalt	7440-48-4	0.5hr	-	0.0028	-	-	-	0.0028	0.3	MECP POI Limit	Sch. 2	Health	No
		24hr	-	-	0.0026	0.0026	0.0029	0.0029	0.1	MECP POI Limit	Sch. 3	Health	
Deuterium	7782-39-0	0.5hr	0.00000316	-	-	-	-	0.00000316	0.3	*De minimus level*	--	--	No
Ethanolamine	141-43-5	0.5hr	11	9.3	-	-	-	11	105	MECP POI Limit	Sch. 2	Health	No
		24hr	-	-	2.02	2.02	2.27	2.27	35	MECP POI Limit	SL-JSL	Health	
Ethylene	74-85-1	0.5hr	0.951	0.77	-	-	-	0.951	0.3	*De minimus level*	--	--	No
Fluoride	7664-39-3	0.5hr	-	0.018	-	-	-	0.018	nv	--	--	--	No[g]
		24hr	-	-	0.02	0.02	0.02	0.02	nv	--	--	--	
		30day	-	-	0.0048	0.0048	0.0015	0.0048	nv	--	--	--	
Formic Acid	64-18-6	0.5hr	2.39	-	-	-	-	2.39	1500	MECP POI Limit	Sch. 2	Health	No
Glycolic Acid	79-14-1	0.5hr	0.0888	-	-	-	-	0.0888	250	TCEQ Short-Term ESL	--	Health	No
Fuel Oil No. 2	68476-30-2	0.5hr	2.79	1.28	-	-	-	2.79	150	MECP POI Limit	Sch. 2	Health	No
Hexane	110-54-3	0.5hr	0.0699	-	-	-	-	0.0699	22500	MECP POI Limit	Sch. 2	Health	No
Hydrazine	302-01-2	Annual	0.00018	0.00033	0.00024	0.00024	0.00023	0.00033	0.0004	US EPA IRIS[h]	--	Health, MAXGLC	No
Hydrogen Chloride	7647-01-0	0.5hr	0.213	-	-	-	-	0.213	60	MECP POI Limit	Sch. 2	Health	No
Hydroquinone	123-31-9	0.5hr	0.0888	-	-	-	-	0.0888	20	TCEQ Short-Term ESL	--	Health	No
Isopropyl Alcohol	67-63-0	0.5hr	0.0213	-	-	-	-	0.0213	22000	MECP POI Limit	Sch. 2	Health	No
Lead	7439-92-1	24hr	-	-	0.00065	0.00065	0.00072	0.00072	0.5	MECP POI Limit	Sch. 3	Health	No
		30day	-	-	0.00019	0.00019	0.000061	0.00019	0.2	MECP POI Limit	Sch. 3	Health	
Lubricating Oil	72623-85-9	0.5hr	-	4.3	-	-	-	4.3	100	MECP POI Limit	Sch. 2	Health & Particulate	No
Manganese	7439-96-5	0.5hr	-	0.33	-	-	-	0.33	1.2	MECP POI Limit	Sch. 2	Health	No
Methane	74-82-8	0.5hr	0.0161	-	-	-	-	0.0161	0.3	*De minimus level*	--	--	No
Methanol	67-56-1	0.5hr	0.671	-	-	-	-	0.671	12000	MECP POI Limit	Sch. 2	Health	No
Methylamine	74-89-5	0.5hr	1.4	0.94			-	1.4	6.4	TCEQ Long-Term ESL	--	Health	No
		24hr	-	-	0.21	0.21	0.24	0.24	6.4	TCEQ Long-Term ESL	--	Health	
Methylene Chloride	75-09-2	0.5hr	2.25	-	-	-	-	2.25	660	MECP POI Limit	Sch. 2	Health	No
Mineral Spirits	N/A	0.5hr	0.0213	-	-	-	-	0.0213	3500	TCEQ Short-Term ESL	Health	nv	Odour
Morpholine	110-91-8	0.5hr	299	253	-	-	-	299	600	MECP POI Limit	Sch. 2	Health	No
		24hr	-	-	37	37	42	42	200	MECP POI Limit	SL-JSL	Health	
Nickel	7440-02-0	0.5hr	-	0.04	-	-	-	0.04	0.6	MECP POI Limit	Sch. 2	Health	No
		24hr	-	-	0.04	0.04	0.04	0.04	2	MECP POI Limit	Sch. 6	URT	
		Annual	-	-	0.00059	0.00059	0.0005	0.00059	0.04	MECP POI Limit	Sch. 3	Health	
Nitric Acid	7697-37-2	0.5hr	0.107	-	-	-	-	0.107	50	TCEQ Short-Term ESL	--	Health	No

Table A.1: Non-Radiological Screening of Air COPCs for Human Health

Contaminant	CAS No.	Averaging Period	Maximum POI Concentration (µg/m³) 2016[b]	2017[c]	2018[d]	2019[e]	2020[f]	2016-2020 Maximum	Screening Criteria: Selected Value (µg/m³)	Source / Basis	O. Reg. 419/05 Schedule Number[a]	Limiting Effect	Carried Forward as COPC for the HHRA?
Nitrogen oxides	10102-44-0	0.5hr	478	125	-	-	-	478	500	MECP POI Limit	Sch. 2	Health	**Yes**
		1hr			**120**	**120**	**157**	**157**	113	CCME CAAQS	--	Health	
		24hr	-	-	10.3	10.3	14.1	14.1	200	MECP POI Limit	Sch. 3	Health	
Particulate matter	N/A	0.5hr	9.16	3	-	-	-	9.16	100	MECP POI Limit	Sch. 2	Visibility	No
	N/A	24hr	*3.10*	*1.01*	-	-	-	*3.10*	27	CCME CAAQS	--	Health	
Phosphoric Acid (as P2O5)	7664-38-2	0.5hr	0.0213	-	-	-	-	0.0213	7	Ontario AAQC (24h)	Health	--	No
Sod ium hypochlorite	7681-52-9	0.5hr	11.9	2.14	-	-	-	11.9	27	MECP POI Limit	Sch. 2	Health	No
		24hr	-	-	0.66	0.66	0.71	0.71	9	MECP POI Limit	SL-PA	Health	
Sulphur dioxide	7446-09-05	0.5hr	333	10.7	-	-	-	333	830	MECP POI Limit	Sch. 2	Health	No
		1hr	-	-	22.8	22.8	23.9	24	183	CCME CAAQS[i]	Sch. 3	Health & Vegetation	
		24hr	-	-	2.82	2.82	2.97	2.97	275	MECP POI Limit	Sch. 3	Health & Vegetation	
Sulphur Hexafluoride	2551-62-4	0.5hr	0.0345	-	-	-	-	0.0345	60000	TCEQ Short-Term ESL	--	Health	No
Sulphuric Acid	7664-93-9	0.5hr	0.0853	-	-	-	-	0.0853	15	MECP POI Limit	Sch. 2	Health	No
Toluene	108-88-3	0.5hr	0.000639	-	-	-	-	0.000639	4500	TCEQ Short-Term ESL	--	Health	No
Total hydrocarbons (Scenerio 1)	N/A	0.5hr	7.07	-	-	-	-	7.07	9.03	Previously approved limit	--	--	No[j]
Total hydrocarbons (Scenerio 2)	N/A	0.5hr	6.47	-	-	-	-	6.47	9.03	Previously approved limit	--	--	No[j]
Trimethylbenzene, 1,2,4-	95-63-6	0.5hr	29.4	-	-	-	-	29.4	4400	TCEQ Short-Term ESL	--	Health	No
Xylenes	1330-20-7	0.5hr	0.00213	-	-	-	-	0.00213	2200	MECP POI Limit	Sch. 2	Health	No

Notes:

POI = Point of Impingement; URT = Upper Risk Threshold; SL-PA = Screening Level - Previously Approved

MAXGLC = Maximum Ground Level Concentration

URT = Upper Risk Threshold

nv = no value

MECP POI Limit = Point of Impingement Limits Under Ontario Regulation 419/05

CCME CAAQS = CCME Canadian Ambient Air Quality Standards

Ontario AAQC = Ontario Ambient Air Quality Criteria (May 1, 2020)

TCEQ ESLs = Texas Commission on Environmental Quality Effects Screening Levels. Short-Term ESLs are used to evaluate 1/2 hour to 1-hour reported air concentrations, and long-term ESLs are used to evaluate annual average concentrations

SL-JSL = Jurisdictional Screening Level

SL-PA = Previously Accepted Screening Level

Italic Text	= Maximum POI concentration was converted from the averaging period used in the dispersion model to the averaging period set by the available risk-based guideline/standard as per Section 17 of O. Reg. 419/05.
Bold Text	= Maximum POI concentration over the 2016-2020 period exceeds screening criteria
-	= Not identified as a significant contaminant for the calendar year.
--	= No associated screening criteria

a - Schedule 2 Standards under O. Reg. 419/05 are revoked as of February 1, 2020. These have been used to screen POI concentrations modelled in 2016 and 2017.

b - There were no modifications to the facility in 2016 (P-CORR-00541-00722); therefore the 2016 emission summary is based on the 2015 ESDM report (P-REP-00541-00014-R001).

c - 2017 ESDM Report (P-REP-00541-10008 R002)

d - 2018 ESDM Report (P-REP-00541-10013-R000)

e - 2019 ESDM Report (P-REP-00541-10019-R000)

f - 2020 ESDM Report (P-REP-00541-10025-R001)

g - There is limited information available concerning inhalation exposure to particulates of inorganic fluoride compounds. Air standards are driven by effects on vegetation and will be considered in the EcoRA.

h - US EPA IRIS Chemical Assessment Summary for Hydrazine/Hydrazine Sulfate, acceptable air concentrations at a cancer risk level of 1 in 1,000,000

i - 1 ppb NO_2 = 1.88 µg/m³; 1 ppb SO_2 = 2.62 µg/m³

j - Although the previously approved limit is not an effects-based limit, total hydrocarbons are considered screened out as they are not required to be identified as a significant contaminant from 2017 to 2020.

Table A.2: Screening of Non-Radiological Final Station Effluent from Condenser Cooling Water for Human Health

Parameters	Unit	PN U1-4 Maximum / Range					PN U5-8 Maximum / Range					2016-2020 Maximum	Screening Criteria		Carried Forward as COPC for the HHRA?
		2016	2017	2018	2019	2020	2016	2017	2018	2019	2020		Selected Value	Source / Basis	
Unionized Ammonia	mg/L	0.015	0.01	0.01	0.06	0.01	0.013	0.01	0.01	0.011	0.011	0.06	None required	GCDWQ (1)[a]	No
Hydrazine	mg/L	**0.008**	**0.009**	**0.01**	**0.017**	**0.009**	**0.007**	**0.009**	**0.005**	**0.017**	**0.025**	**0.025**	0.00001	US EPA IRIS (2)	**Yes**
Morpholine	mg/L	0.006	0.002	0.003	0.135	0.135	0.047	0.034	0.059	0.01	0.005	0.135	1.7	HC (3)	No
pH	pH units	7.7-8.4	7.7-8.2	7.8-8.3	7.6-8.7	8.0-8.3	7.9-8.4	7.9-8.4	7.9-8.3	7.9-8.5	7.9-8.5	7.7-8.5	None	GCDWQ (1)[b]	No
Total Residual Chlorine (TRC)	mg/L	0.003	0.005	0.002	0.003	0.005	0.0033	0.0038	0.0038	0.003	0.024	0.024	None required	GCDWQ (1)[c]	No

Notes:

a - A maximum allowable concentration for ammonia is not required according to the GCDWQ. Ammonia is naturally occurring or added as part of chloramination for drinking water disinfection.

b - HC recommends a range of 7.0-10.5; the control of pH is important to maximize treatment effectiveness, control corrosion and reduce leaching from distribution system and plumbing (HC 2020)components.

c - Free chlorine concentrations in most Canadian drinking water distribution systems range from 0.04 to 2.0 mg/L.

Bold Text = 2016-2020 maximum exceeds screening criteria

References:

1. Health Canada (HC). 2020. Guidelines for Canadian Drinking Water Quality—Summary Table. Water and Air Quality Bureau, Healthy Environmentsand Consumer Safety Branch, Health Canada, Ottawa, Ontario. September.
2. US EPA Integrated Risk Information System (IRIS). 1988. Chemical Assessment Summary - Hydrazine/Hydrazine sulfate; CASRN 302-01-2. Drinking Water Concentration with 1 in 100,000 risk level.
3. Health Canada (HC). 2002. A Summary of the Health Hazard Assessment of Morpholine in Wax Coatings of Apples. https://www.canada.ca/en/health-canada/services/food-nutrition/food-safety/information-product/summary-health-hazard-assessment-morpholine-coatings-apples.html. [Converted TDI (0.48 mg/kgBW/day) to DW criterion.]

Table A.3: Screening of Lake Water COPCs for Human Health

Parameters	Unit	2015 Lake Water Results		Screening Criteria		Carried Forward as COPC for the HHRA?
		Mean Background in 2015 (LWC-1)	Maximum Observed Lake Water in 2015	Selected Screening Level	Source / Basis	
General Chemistry						
Alkalinity (Total as CaCO3)	mg/L	93	110	--	Note (a)	No
Ammonia Nitrogen	mg/L	<0.05	<0.05	--	Note (b)	No
Unionized Ammonia, calculated	mg/L	<0.0016	<0.0020	None required	GCDWQ (1)	No
Biochemical Oxygen Demand, 5 Day	mg/L	2.25	3	--	Note (b)	No
Chemical Oxygen Demand	mg/L	5.4	8.6	--	Note (b)	No
Conductivity	ms/cm	0.314	0.5	--	Note (b)	No
Conductivity, field measured	ms/cm	0.259	0.375	--	Note (b)	No
Hardness, Calcium Carbonate	mg/L	127.5	160	None required	GCDWQ (1), Note (a)	No
Temperature, field measured	C	12.33	23.11	--	Note (b)	No
Total Suspended Solids	mg/L	<1-<10	6	--	Note (b)	No
pH	pH units	7.9025	8.18	None	GCDWQ (1)	No
pH, field measured	pH units	8.14	8.34	None	GCDWQ (1)	No
Total Residual Chlorine, field measured	mg/L	<0.0012	<0.0012	None required	GCDWQ (1)	No
Metals/Metalloids						
Aluminum	mg/L	0.007	0.033	0.1	GCDWQ (1)	No
Aluminum, filtered	mg/L	0.009	<0.0050	0.1	GCDWQ (1)	No
Antimony	mg/L	<0.0005	<0.0005	0.006	GCDWQ (1)	No
Arsenic	mg/L	<0.0010	<0.0011	0.01	GCDWQ (1)	No
Barium	mg/L	0.02225	0.024	1	ODWS (2)	No
Beryllium	mg/L	<0.0005	<0.0005	0.004	MECP GW1 (3)	No
Bismuth	mg/L	<0.001	<0.001	<0.001	LWC-1 Bkgrd	No
Boron	mg/L	0.0255	0.028	5	GCDWQ (1)	No
Cadmium	mg/L	0.0000095	0.000019	0.005	ODWS (2)	No
Calcium	mg/L	34	37	None required	GCDWQ (1)	No
Chromium	mg/L	<0.0050	<0.0050	0.05	GCDWQ (1)	No
Cobalt	mg/L	<0.0005	<0.0005	0.003	MECP GW1 (3)	No
Copper	mg/L	<0.0010	0.0088	1	MECP GW1 (3)	No
Iron	mg/L	<0.1	<0.1	0.3	GCDWQ (1), Note (e)	No
Lead	mg/L	<0.0005	<0.0005	0.01	ODWS (2)	No
Lithium	mg/L	<0.005	<0.005	<0.005	LWC-1 Bkgrd	No
Magnesium	mg/L	8.775	9	None required	GCDWQ (1)	No
Manganese	mg/L	<0.0020	0.017	0.05	MECP GW1 (3)	No
Mercury	mg/L	0.00001	0.00001	0.001	GCDWQ (1)	No
Molybdenum	mg/L	0.0013	0.0014	0.07	MECP GW1 (3)	No
Nickel	mg/L	0.001025	0.0015	0.1	MECP GW1 (3)	No
Potassium	mg/L	1.625	1.7	--	Note (c)	No
Selenium	mg/L	0.00013875	0.00021	0.01	ODWS (2)	No
Silicon	mg/L	0.26	0.66	--	Note (d)	No
Silver	mg/L	<0.0001	<0.0001	none required	GCDWQ (1)	No
Sodium	mg/L	14.5	23	≤200	GCDWQ (1), Note (e)	No
Strontium	mg/L	0.18	0.19	7	GCDWQ (1)	No
Tellurium	mg/L	<0.0010	<0.0010	<0.001	LWC-1 Bkgrd	No
Thallium	mg/L	<0.000050	<0.000050	<0.000	LWC-1 Bkgrd	No
Tin	mg/L	<0.0010	<0.0010	<0.001	LWC-1 Bkgrd	No
Titanium	mg/L	<0.005	<0.005	<0.005	LWC-1 Bkgrd	No
Tungsten	mg/L	<0.0010	<0.0010	<0.001	LWC-1 Bkgrd	No
Uranium	mg/L	0.0003675	0.00042	0.02	GCDWQ (1)	No
Vanadium	mg/L	<0.0005	0.00059	0.0062	MECP GW1 (3)	No
Zinc	mg/L	<0.0050	0.0062	≤5	GCDWQ (1), Note (e)	No
Zirconium	mg/L	<0.0010	<0.0010	<0.001	LWC-1 Bkgrd	No
Petroleum Hydrocarbons						
PHC F1(C6-C10)-BTEX	mg/L	<0.025	<0.025	0.82	MECP GW1 (3)	No
PHC F1 (C6-C10)	mg/L	<0.025	<0.025	0.82	MECP GW1 (3)	No
PHC F2 (C10-C16)	mg/L	<0.1	<0.1	0.3	MECP GW1 (3)	No
PHC F3 (C16-C34)	mg/L	<0.2	<0.2	1	MECP GW1 (3)	No
PHC F4 (C34-C50)	mg/L	<0.2	<0.2	1.1	MECP GW1 (3)	No
Other						
Hydrazine	mg/L	-	0.00025[f]	0.00001	US EPA IRIS (4)	**Yes**
Morpholine	mg/L	<0.004	0.006	1.7	HC (5)	No
Radionuclides						
Carbon-14	Bq/L	<0.1	<0.1	200	ODWS (2)	**Yes** Assessed quantitatively for public interest purposes
Cesium-134	Bq/L	<0.1	<0.3	7	ODWS (2)	
Cesium-137	Bq/L	<0.1	<0.1	10	GCDWQ (1)	
Cobalt-60	Bq/L	<0.1	<0.1	2	ODWS (2)	
Tritium	Bq/L	<4.4	69.1	7000	GCDWQ (1)	

Notes:

Bold Text	= Maximum POI concentration over the 2016-2020 period exceeds screening criteria
-	= Not identified as a significant contaminant for the calendar year.
--	= No associated screening criteria

a - Hardness is dependent on local, naturally occurring conditions; no guideline is required under the GCDWQ. Likewise, no screening levels have been selected for hardness and hardness-related parameters (e.g. alkalinity)

b - Risk-based guidelines are not applicable to water quality parameters such as conductivity, temperature, biological oxygen demand, chemical oxygen demand, and total suspended solids and therefore are excluded from screening.

c - Potassium is an essential electrolyte in the human body and is not applicable for screening of risk to human health.

d - There are no human health risk-based guidelines for silicon. Silicon is an abundant element in the earth's crust and has not been shown to have adverse effects on human health.

e - Zinc and iron are considered non-toxic at levels found in drinking water, the GCDWQ is based on aesthetic objectives (taste, staining). Aesthetic objective for sodium is based on guidelines for persons with sodium-reduced diets.

f - Maximum value from 2014 Supplementary EMP Study (Ecometrix, 2015)

References:

1. Health Canada (HC). 2020. Guidelines for Canadian Drinking Water Quality—Summary Table. Water and Air Quality Bureau, Healthy Environments and Consumer Safety Branch, Health Canada, Ottawa, Ontario. September.

2. Ontario Regulation 169/03: Ontario Drinking Water Quality Standards, made under the Safe Drinking Water Act, 2002

3. Ministry of Environment (MOE) 2011. Rationale for the Development of Soil, Ground Water and Sediment Standards in Ontario Under Part XV.1 of the Environmental Protection Act. GW1 Component Value Protective of Drinking Water

4. US EPA Integrated Risk Information System (IRIS). 1988. Chemical Assessment Summary - Hydrazine/Hydrazine sulfate; CASRN 302-01-2. Drinking Water Concentration with 1 in 100,000 risk level.

5. Health Canada (HC). 2002. A Summary of the Health Hazard Assessment of Morpholine in Wax Coatings of Apples. https://www.canada.ca/en/health-canada/services/food-nutrition/food-safety/information-product/summary-health-hazard-assessment-morpholine-coatings-apples.html. [Converted TDI (0.48

Table A.4a: Screening of Storm Water COPCs for Human Health - PN U1-4

		Catchment 2				Catchment 1				Maximum Concentration in Discharge	Final Concentration in CCW	Screening Criteria		Mean Background in 2015 (LWC-1)	Carried Forward as COPC for the HHRA?
	Station ID	MH137				MH149						Selected Screening Level	Source / Basis		
	Sample 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						
General	**Unit**														
Chloride	mg/L	25	25	27	24	650	110	790	150	790	1.5	250	AO	-	No
Conductivity	mS/cm	0.31	0.301	0.323	0.29	2.32	0.521	2.99	0.714	2.99	-	--	Note (b)	0.3135	No
Hardness, Calcium Carbonate	mg/L	120	120	130	120	260	93	430	98	430	1	None required	GCDWQ (1), Note (a)	127.5	No
pH	pH units	7.97	8.03	8.12	8.01	7.72	7.81	8.11	7.66	8.12	-	None	GCDWQ (1)	7.9025	No
Phosphorous	mg/L	0.026	0.059	0.025	0.023	0.069	0.044	0.029	0.11	0.11	0.0002	--	Note (f)	-	No
Total Suspended Solids	mg/L	< 10	46	< 10	<10	57	17	< 10	70	70	0.1	--	Note (b)	<1-<10	No
Metals															
Aluminum	µg/L	67	300	110	19	680	350	57	1400	1400	3	100	GCDWQ (1)	7.075	No
Antimony	µg/L	< 0.50	< 0.50	< 0.50	<0.50	1	< 0.50	0.59	0.56	1	0.002	6	GCDWQ (1)	<0.5	No
Arsenic	µg/L	< 1.0	< 1.0	< 1.0	<1.0	< 1.0	< 1.0	< 1.0	<1.0	< 1	<0.002	10	GCDWQ (1)	<1	No
Barium	µg/L	26	28	26	22	64	19	67	31	67	0.1	1000	ODWS (2)	22.25	No
Beryllium	µg/L	< 0.50	< 0.50	< 0.50	<0.50	< 0.50	< 0.50	< 0.50	<0.50	< 0.5	<0.001	4	MECP GW1 (3)	<0.5	No
Bismuth	µg/L	< 1.0	< 1.0	< 1.0	<1.0	< 1.0	< 1.0	< 1.0	1.2	1.2	0.002	<1	LWC-1 Bkgrd	<1	No
Boron	µg/L	26	19	24	15	32	11	19	<10	32	0.06	5000	GCDWQ (1)	25.5	No
Cadmium	µg/L	< 0.10	< 0.10	< 0.10	<0.10	< 0.10	< 0.10	< 0.10	<0.10	< 0.1	<0.0002	5	ODWS (2)	0.0095	No
Calcium	µg/L	35000	38000	38000	32000	96000	29000	140000	48000	140000	274	None required	GCDWQ (1)	34000	No
Chromium	µg/L	< 5.0	< 5.0	< 5.0	<5.0	< 5.0	< 5.0	< 5.0	<5.0	< 5	<0.01	50	GCDWQ (1)	<5	No
Cobalt	µg/L	< 0.50	< 0.50	< 0.50	<0.50	0.65	< 0.50	< 0.50	1	1	0.002	3	MECP GW1 (3)	<0.5	No
Copper	µg/L	3.7	5.7	3.7	1.9	7.3	6.5	3.7	8.6	8.6	0.02	1000	MECP GW1 (3)	<1	No
Iron	µg/L	110	570	200	<100	1200	450	130	1800	1800	4	300	GCDWQ (1), Note (e)	<100	No
Lead	µg/L	< 0.50	1.1	< 0.50	<0.50	2.7	1.5	< 0.50	5.2	5.2	0.01	10	ODWS (2)	<0.5	No
Lithium	µg/L	< 5.0	< 5.0	< 5.0	<5.0	< 5.0	< 5.0	< 5.0	<5.0	< 5	<0.01	<5	LWC-1 Bkgrd	<5	No
Magnesium	µg/L	8900	8400	8700	8100	13000	3500	20000	5200	20000	39	None required	GCDWQ (1)	8775	No
Manganese	µg/L	13	37	9.3	2.8	110	59	16	120	120	0.2	50	MECP GW1 (3)	<2	No
Mercury (filtered)	µg/L	< 0.01	< 0.01	< 0.01	<0.01	< 0.01	< 0.01	< 0.01	<0.01	< 0.01	<0.00002	1	GCDWQ (1)	0.01	No
Molybdenum	µg/L	1.2	0.96	1.2	1.1	1.3	< 0.50	1.2	0.64	1.3	0.003	70	MECP GW1 (3)	1.3	No
Nickel	µg/L	< 1.0	1.3	< 1.0	<1.0	2.5	< 1.0	< 1.0	2.6	2.6	0.005	100	MECP GW1 (3)	1.025	No
Potassium	µg/L	1700	1600	1700	1600	2200	1100	2400	1900	2400	5	--	Note (c)	1625	No
Selenium	µg/L	< 2.0	< 2.0	< 2.0	<2.0	< 2.0	< 2.0	< 2.0	<2.0	< 2	<0.004	10	ODWS (2)	0.13875	No
Silicon	µg/L	240	810	530	370	2900	1300	2800	3400	3400	7	--	Note (d)	260	No
Silver	µg/L	< 0.10	< 0.10	< 0.10	<0.10	< 0.10	< 0.10	< 0.10	<0.10	< 0.1	<0.0002	none required	GCDWQ (1)	<0.1	No
Sodium	µg/L	15000	14000	16000	14000	380000	63000	430000	99000	430000	842	≤200	GCDWQ (1), Note (e)	14500	No
Strontium	µg/L	180	170	190	170	680	190	890	300	890	2	7	GCDWQ (1)	180	No
Tellurium	µg/L	< 1.0	< 1.0	< 1.0	<1.0	< 1.0	< 1.0	< 1.0	<1.0	< 1	<0.002	<1	LWC-1 Bkgrd	<1	No
Thallium	µg/L	< 0.050	< 0.050	< 0.050	<0.050	< 0.050	< 0.050	< 0.050	0.053	0.053	0.0001	<0.05	LWC-1 Bkgrd	<0.05	No
Tin	µg/L	< 1.0	< 1.0	< 1.0	<1.0	< 1.0	< 1.0	< 1.0	<1.0	< 1	<0.002	<1	LWC-1 Bkgrd	<1	No
Titanium	µg/L	< 5.0	16	7.1	<5.0	30	11	< 5.0	49	49	0.1	<5	LWC-1 Bkgrd	<5	No
Tungsten	µg/L	< 1.0	< 1.0	< 1.0	<1.0	< 1.0	< 1.0	< 1.0	<1.0	< 1	<0.002	<1	LWC-1 Bkgrd	<1	No
Uranium	µg/L	0.89	0.46	0.62	0.45	0.3	0.33	0.58	0.37	0.89	0.002	20	GCDWQ (1)	0.3675	No
Vanadium	µg/L	0.53	1.1	< 0.50	<0.50	2.9	1.2	< 0.50	3.6	3.6	0.007	6.2	MECP GW1 (3)	<0.5	No
Zinc	µg/L	< 5.0	20	12	<5.0	83	43	39	84	84	0.2	≤5	GCDWQ (1), Note (e)	<5	No
Zirconium	µg/L	< 1.0	< 1.0	< 1.0	<1.0	< 1.0	< 1.0	< 1.0	1.1	1.1	0.002	<1	LWC-1 Bkgrd	<1	No

Table A.4a: Screening of Storm Water COPCs for Human Health - PN U1-4

		Catchment 2				Catchment 1				Maximum Concentration in Discharge	Final Concentration in CCW	Screening Criteria		Mean Background in 2015 (LWC-1)	Carried Forward as COPC for the HHRA?
Station ID		MH137				MH149						Selected Screening Level	Source / Basis		
Sample 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						
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	<0.0004	5	GCDWQ (1)	-	No
Toluene	µg/L	0.22	< 0.20	< 0.20	<0.20	< 0.20	< 0.20	< 0.20	<0.20	0.22	0.0004	60	GCDWQ (1)	-	No
Ethylbenzene	µg/L	< 0.20	< 0.20	< 0.20	<0.20	< 0.20	< 0.20	< 0.20	<0.20	< 0.2	<0.0004	140	GCDWQ (1)	-	No
o-Xylene	µg/L	< 0.20	< 0.20	< 0.20	<0.20	< 0.20	< 0.20	< 0.20	<0.20	< 0.2	<0.0004	--	See total xylenes	-	No
m,p-Xylenes	µg/L	< 0.40	< 0.40	< 0.40	<0.40	< 0.40	< 0.40	< 0.40	<0.40	< 0.4	<0.0008	--	See total xylenes	-	No
Xylenes, Total	µg/L	< 0.40	< 0.40	< 0.40	<0.40	< 0.40	< 0.40	< 0.40	<0.40	< 0.4	<0.0008	90	GCDWQ (1)	-	No
Petroleum Hydrocarbons - F1 (C6-C10)-BTEX	µg/L	< 25	< 25	< 25	<25	< 25	< 25	< 25	<25	< 25	<0.05	820	MECP GW1 (3)	<25	No
Petroleum Hydrocarbons - F1 (C6-C10)	µg/L	< 25	< 25	< 25	<25	< 25	< 25	< 25	<25	< 25	<0.05	820	MECP GW1 (3)	<25	No
Petroleum Hydrocarbons - F2 (C10-C16)	µg/L	< 100	< 100	< 100	<100	< 100	< 100	< 100	<100	< 100	<0.2	300	MECP GW1 (3)	<100	No
Petroleum Hydrocarbons - F3 (C16-C34)	µg/L	< 200	< 200	< 200	<200	< 200	< 200	< 200	<200	< 200	<0.4	1000	MECP GW1 (3)	<200	No
Petroleum Hydrocarbons - F4 (C34-C50)	µg/L	< 200	< 200	< 200	<200	< 200	< 200	< 200	<200	< 200	<0.4	1100	MECP GW1 (3)	<200	No
Radiological															
Carbon-14	Bq/L	< 20	< 20	< 20	<20	< 20	< 20	< 20	<20	< 20	<0.04	200	ODWS (2)	<0.1	No
Cesium-134	Bq/L	< 1	< 1	< 1	<1	< 1	< 1	< 1	<1	< 1	<0.002	7	ODWS (2)	<0.1	No
Cesium-137	Bq/L	< 1	< 1	< 1	<1	< 1	< 1	< 1	<1	< 1	<0.002	10	GCDWQ (1)	<0.1	No
Cobalt-60	Bq/L	-	< 1	< 1	<1	-	< 1	< 1	<1	< 1	<0.002	2	ODWS (2)	<0.1	No
Iodine-131	Bq/L	< 1	< 1	< 1	<1	< 1	< 1	< 1	<1	< 1	<0.002	6	ODWS (2)	-	No
Manganese-54	Bq/L	< 1	-	-	-	< 1	-	-	-	< 1	<0.002	200	ODWS (2)	-	No
Tritium (HTO)	Bq/L	21	588	145	163	327	141	882	235	882	2	7000	GCDWQ (1)	<4.4	No
Zinc-65	Bq/L	< 1	-	-	-	< 1	-	-	-	< 1	<0.002	40	ODWS (2)	-	No

Notes:

a - Hardness is dependent on local, naturally occurring conditions; no guideline is required under the GCDWQ. Likewise, no screening levels have been selected for hardness and hardness-related parameters (e.g. alkalinity)

b - Risk-based guidelines are not applicable to water quality parameters such as conductivity, temperature, biological oxygen demand, chemical oxygen demand, and total suspended solids and therefore are excluded from screening.

c - Potassium is an essential electrolyte in the human body and is not applicable for screening of risk to human health.

d - There are no human health risk-based guidelines for silicon. Silicon is an abundant element in the earth's crust and has not been shown to have adverse effects on human health.

e - Zinc, iron and chloride are considered non-toxic at levels found in drinking water, the GCDWQ is based on aesthetic objectives (taste, staining). Aesthetic objective for sodium is based on guidelines for persons with sodium-reduced diets.

f - Phosphorus in drinking water is not harmful to human health; and is further screened for the ecological risk assessment.

References:

1. Health Canada (HC). 2020. Guidelines for Canadian Drinking Water Quality—Summary Table. Water and Air Quality Bureau, Healthy Environments and Consumer Safety Branch, Health Canada, Ottawa, Ontario. September.
2. Ontario Regulation 169/03: Ontario Drinking Water Quality Standards, made under the Safe Drinking Water Act, 2002
3. Ministry of Environment (MOE) 2011. Rationale for the Development of Soil, Ground Water and Sediment Standards in Ontario Under Part XV.1 of the Environmental Protection Act. GW1 Component Value Protective of Drinking Water

Bold Text	= Final concentration in lake exceeds screening criteria
-	= No data available
--	= No associated screening criteria

Table A.4b: Screening of Storm Water COPCs for Human Health - PN U5-8

		Catchment 8					Catchment 6				Maximum Concentration in Discharge	Final Concentration in CCW	Screening Criteria		Mean Background in 2015 (LWC-1)	Carried Forward as COPC for the HHRA?
	Station ID	M3-3					MH15						Selected Screening Level	Source / Basis		
	Sample Date	20-Aug-15	19-Nov-15	28-Oct-15	11-Jun-16		20-Aug-15	28-Oct-15	19-Nov-15	11-Jun-16						
General	**Unit**					Dup of M3-3										
Chloride	mg/L	650	340	120	200	200	47	40	38	14	650	2	250	AO	-	No
Conductivity	mS/cm	2.36	1.4	0.541	0.922	0.944	0.276	0.35	0.305	0.12	2.36	0.006	--	Note (b)	0.3135	No
Hardness, Calcium Carbonate	mg/L	160	120	69	90	90	49	99	86	30	160	0.4	None required	GCDWQ (1), Note (a)	127.5	No
pH	pH units	7.91	7.83	7.77	7.91	7.87	7.47	7.85	7.84	7.8	7.91	-	None	GCDWQ (1)	7.9025	No
Phosphorous	mg/L	0.029	0.025	0.037	0.05	0.052	0.54	0.16	0.27	0.13	0.54	0.001	--	Note (f)	-	No
Total Suspended Solids	mg/L	< 10	< 10	13	47	34	19	16	66	15	66	0.18	--	Note (b)	<1-<10	No
Metals																
Aluminum	µg/L	110	79	460	390	370	270	210	1300	440	1300	3.5	100	GCDWQ (1)	7.075	No
Antimony	µg/L	0.56	0.52	0.51	0.95	0.91	0.64	0.84	< 0.50	0.93	0.95	0.003	6	GCDWQ (1)	<0.5	No
Arsenic	µg/L	< 1.0	< 1.0	< 1.0	1.4	1.5	< 1.0	< 1.0	< 1.0	<1.0	1.5	0.004	10	GCDWQ (1)	<1	No
Barium	µg/L	37	21	12	20	20	14	24	25	8.5	37	0.1	1000	ODWS (2)	22.25	No
Beryllium	µg/L	< 0.50	< 0.50	< 0.50	<0.50	<0.50	< 0.50	< 0.50	< 0.50	<0.50	< 0.5	<0.001	4	MECP GW1 (3)	<0.5	No
Bismuth	µg/L	< 1.0	< 1.0	< 1.0	<1.0	<1.0	< 1.0	< 1.0	< 1.0	<1.0	< 1	<0.003	<1	LWC-1 Bkgrd	<1	No
Boron	µg/L	45	14	< 10	13	12	16	17	12	<10	45	0.1	5000	GCDWQ (1)	25.5	No
Cadmium	µg/L	< 0.10	< 0.10	< 0.10	0.2	0.23	< 0.10	< 0.10	< 0.10	<0.10	0.23	0.0006	5	ODWS (2)	0.0095	No
Calcium	µg/L	52000	38000	21000	39000	38000	19000	27000	36000	14000	52000	139	None required	GCDWQ (1)	34000	No
Chromium	µg/L	< 5.0	< 5.0	< 5.0	5.1	<5.0	< 5.0	< 5.0	< 5.0	<5.0	5.1	0.01	50	GCDWQ (1)	<5	No
Cobalt	µg/L	< 0.50	< 0.50	< 0.50	0.97	0.95	< 0.50	< 0.50	0.88	<0.50	0.97	0.003	3	MECP GW1 (3)	<0.5	No
Copper	µg/L	6.2	3.6	5	12	11	11	7.1	7.4	7.5	12	0.03	1000	MECP GW1 (3)	<1	No
Iron	µg/L	370	130	550	710	660	340	280	1600	510	1600	4	300	GCDWQ (1), Note (e)	<100	No
Lead	µg/L	0.66	0.54	1.8	3.1	2.9	1.3	0.89	2.2	1.6	3.1	0.01	10	ODWS (2)	<0.5	No
Lithium	µg/L	< 5.0	< 5.0	< 5.0	<5.0	<5.0	< 5.0	< 5.0	< 5.0	<5.0	< 5	<0.01	<5	LWC-1 Bkgrd	<5	No
Magnesium	µg/L	6800	5300	2000	3300	3200	2200	4800	4700	1000	6800	18	None required	GCDWQ (1)	8775	No
Manganese	µg/L	96	20	33	60	60	27	20	63	24	96	0.3	50	MECP GW1 (3)	<2	No
Mercury (filtered)	µg/L	< 0.01	< 0.01	< 0.01	<0.01	0.01	< 0.01	< 0.01	0.02	<0.01	0.02	0.00005	1	GCDWQ (1)	0.01	No
Molybdenum	µg/L	1.1	0.66	< 0.50	3.3	3.4	0.54	1.3	0.55	0.71	3.4	0.01	70	MECP GW1 (3)	1.3	No
Nickel	µg/L	1.6	1	1.3	4.1	3.6	< 1.0	< 1.0	2.4	<1.0	4.1	0.01	100	MECP GW1 (3)	1.025	No
Potassium	µg/L	1300	960	900	10000	9700	1200	1500	1200	1200	10000	27	--	Note (c)	1625	No
Selenium	µg/L	< 2.0	< 2.0	< 2.0	<2.0	<2.0	< 2.0	< 2.0	< 2.0	<2.0	< 2	<0.005	10	ODWS (2)	0.13875	No
Silicon	µg/L	1100	760	1100	2300	2200	1100	1500	3100	1100	3100	8	--	Note (d)	260	No
Silver	µg/L	< 0.10	< 0.10	< 0.10	<0.10	<0.10	< 0.10	< 0.10	< 0.10	<0.10	< 0.1	<0.0003	none required	GCDWQ (1)	<0.1	No
Sodium	µg/L	420000	220000	77000	140000	130000	35000	31000	27000	9900	420000	1122	≤200	GCDWQ (1), Note (e)	14500	No
Strontium	µg/L	390	230	120	290	280	300	770	670	86	770	2	7	GCDWQ (1)	180	No
Tellurium	µg/L	< 1.0	< 1.0	< 1.0	<1.0	<1.0	< 1.0	< 1.0	< 1.0	<1.0	< 1	<0.003	<1	LWC-1 Bkgrd	<1	No
Thallium	µg/L	< 0.050	< 0.050	< 0.050	<0.050	<0.050	< 0.050	< 0.050	< 0.050	<0.050	< 0.05	<0.0001	<0.05	LWC-1 Bkgrd	<0.05	No
Tin	µg/L	< 1.0	< 1.0	< 1.0	6.1	6.1	< 1.0	< 1.0	< 1.0	<1.0	6.1	0.02	<1	LWC-1 Bkgrd	<1	No
Titanium	µg/L	6.3	5.4	16	16	16	18	7.9	44	23	44	0.1	<5	LWC-1 Bkgrd	<5	No
Tungsten	µg/L	< 1.0	< 1.0	< 1.0	<1.0	<1.0	< 1.0	< 1.0	< 1.0	<1.0	< 1	<0.003	<1	LWC-1 Bkgrd	<1	No
Uranium	µg/L	0.16	0.24	< 0.10	0.21	0.22	< 0.10	0.32	0.17	0.13	0.32	0.001	20	GCDWQ (1)	0.3675	No
Vanadium	µg/L	2.4	0.91	2.1	8.3	8.2	3.8	1.3	3.6	2.2	8.3	0.02	6.2	MECP GW1 (3)	<0.5	No
Zinc	µg/L	39	41	40	73	71	160	80	130	91	160	0.4	≤5	GCDWQ (1), Note (e)	<5	No
Zirconium	µg/L	< 1.0	< 1.0	< 1.0	<1.0	<1.0	< 1.0	< 1.0	< 1.0	<1.0	< 1	<0.003	<1	LWC-1 Bkgrd	<1	No

Table A.4b: Screening of Storm Water COPCs for Human Health - PN U5-8

Parameter	Unit	Catchment 8 M3-3 20-Aug-15	Catchment 8 M3-3 19-Nov-15	Catchment 8 M3-3 28-Oct-15	Catchment 8 M3-3 11-Jun-16		Catchment 6 MH15 20-Aug-15	Catchment 6 MH15 28-Oct-15	Catchment 6 MH15 19-Nov-15	Catchment 6 MH15 11-Jun-16	Maximum Concentration in Discharge	Final Concentration in CCW	Screening Criteria: Selected Screening Level	Screening Criteria: Source / Basis	Mean Background in 2015 (LWC-1)	Carried Forward as COPC for the HHRA?
Petroleum Hydrocarbons (and BTEX)																
Benzene	µg/L	< 0.20	< 0.20	< 0.20	<0.20	<0.20	< 0.20	< 0.20	< 0.20	<0.20	< 0.2	<0.0005	5	GCDWQ (1)	-	No
Toluene	µg/L	0.31	< 0.20	< 0.20	<0.20	<0.20	< 0.20	< 0.20	< 0.20	<0.20	0.31	0.001	60	GCDWQ (1)	-	No
Ethylbenzene	µg/L	< 0.20	< 0.20	< 0.20	<0.20	<0.20	< 0.20	< 0.20	< 0.20	<0.20	< 0.2	<0.0005	140	GCDWQ (1)	-	No
o-Xylene	µg/L	< 0.20	< 0.20	< 0.20	<0.20	<0.20	< 0.20	< 0.20	0.38	<0.20	0.38	0.001	--	See total xylenes	-	No
m,p-Xylenes	µg/L	< 0.40	< 0.40	< 0.40	<0.40	<0.40	< 0.40	< 0.40	0.46	<0.40	0.46	0.001	--	See total xylenes	-	No
Xylenes, Total	µg/L	< 0.40	< 0.40	< 0.40	<0.40	<0.40	< 0.40	< 0.40	0.84	<0.40	0.84	0.002	90	GCDWQ (1)	-	No
Petroleum Hydrocarbons - F1 (C6-C10)-BTEX	µg/L	< 25	< 25	< 25	<25	<25	< 25	< 25	< 25	<25	< 25	<0.07	820	MECP GW1 (3)	<25	No
Petroleum Hydrocarbons - F1 (C6-C10)	µg/L	< 25	< 25	< 25	<25	<25	< 25	< 25	< 25	<25	< 25	<0.07	820	MECP GW1 (3)	<25	No
Petroleum Hydrocarbons - F2 (C10-C16)	µg/L	< 100	< 100	< 100	<100	<100	< 100	< 100	< 100	<100	< 100	<0.3	300	MECP GW1 (3)	<100	No
Petroleum Hydrocarbons - F3 (C16-C34)	µg/L	< 200	< 200	< 200	<200	<200	< 200	< 200	< 200	<200	< 200	<0.5	1000	MECP GW1 (3)	<200	No
Petroleum Hydrocarbons - F4 (C34-C50)	µg/L	< 200	< 200	< 200	<200	<200	< 200	< 200	< 200	<200	< 200	<0.5	1100	MECP GW1 (3)	<200	No
Radiological																
Carbon-14	Bq/L	< 20	< 20	< 20	<20	<20	< 20	< 20	< 20	<20	< 20	<0.05	200	ODWS (2)	<0.1	No
Cesium-134	Bq/L	< 1	< 1	< 1	<1	<1	< 1	< 1	< 1	<1	< 1	<0.003	7	ODWS (2)	<0.1	No
Cesium-137	Bq/L	< 1	< 1	< 1	<1	<1	< 1	< 1	< 1	<1	< 1	<0.003	10	GCDWQ (1)	<0.1	No
Cobalt-60	Bq/L	-	< 1	< 1	<1	<1	-	< 1	< 1	<1	< 1	<0.003	2	ODWS (2)	<0.1	No
Iodine-131	Bq/L	< 1	< 1	< 1	<1	<1	< 1	< 1	< 1	<1	< 1	<0.003	6	ODWS (2)	-	No
Manganese-54	Bq/L	< 1	-	-	-	-	< 1	-	-	-	< 1	<0.003	200	ODWS (2)	-	No
Tritium (HTO)	Bq/L	974	145	50	78	79	182	1400	1110	1370	1400	4	7000	GCDWQ (1)	<4.4	No
Zinc-65	Bq/L	< 1	-	-	-	-	< 1	-	-	-	< 1	<0.003	40	ODWS (2)	-	No

Notes:

a - Hardness is dependent on local, naturally occurring conditions; no guideline is required under the GCDWQ. Likewise, no screening levels have been selected for hardness and hardness-related parameters (e.g. alkalinity)

b - Risk-based guidelines are not applicable to water quality parameters such as conductivity, temperature, biological oxygen demand, chemical oxygen demand, and total suspended solids and therefore are excluded from screening.

c - Potassium is an essential electrolyte in the human body and is not applicable for screening of risk to human health.

d - There are no human health risk-based guidelines for silicon. Silicon is an abundant element in the earth's crust and has not been shown to have adverse effects on human health.

e - Zinc, iron and chloride are considered non-toxic at levels found in drinking water, the GCDWQ is based on aesthetic objectives (taste, staining). Aesthetic objective for sodium is based on guidelines for persons with sodium-reduced diets.

f - Phosphorus in drinking water is not harmful to human health; and is further screened for the ecological risk assessment.

References:

1. Health Canada (HC). 2020. Guidelines for Canadian Drinking Water Quality—Summary Table. Water and Air Quality Bureau, Healthy Environments and Consumer Safety Branch, Health Canada, Ottawa, Ontario. September.

2. Ontario Regulation 169/03: Ontario Drinking Water Quality Standards, made under the Safe Drinking Water Act, 2002

3. Ministry of Environment (MOE) 2011. Rationale for the Development of Soil, Ground Water and Sediment Standards in Ontario Under Part XV.1 of the Environmental Protection Act. GW1 Component Value Protective of Drinking Water

Bold Text	= Final concentration in lake exceeds screening criteria
-	= No data available
--	= No associated screening criteria

Table A.4c: Screening of Storm Water COPCs for Human Health - Lake Water East

Location / Station ID / Date	Units	Concentration: Catchment 10 M2-1 20-Aug-15	28-Oct-15	19-Nov-15	11-Jun-16	Concentration: Catchment 13 M5-1 20-Aug-15	28-Oct-15	19-Nov-15	11-Jun-16	Loading Units	Loading: Catchment 10 M2-1 20-Aug-15	28-Oct-15	19-Nov-15	11-Jun-16	Loading: Catchment 13 M5-1 20-Aug-15	28-Oct-15	19-Nov-15	11-Jun-16	Max Loading	Screening Units	Final Concentration in Lake	Screening Criteria: Selected Screening Level	Screening Criteria: Source / Basis	Mean Background in 2015 (LWC-1)	Carried Forward as COPC for the HHRA?
General																									
Chloride	mg/L	600	110	890	180	320	16	340	92	mg/s	1136	1550	561	8700	11872	1106	3093	25283	25283	mg/L	1	250	AO	-	No
Conductivity	mS/cm	2.2	0.539	3.38	0.814	1.36	0.135	1.59	0.455	mS/cm	4.16	7.60	2.13	39.34	50.46	9.33	14.46	125.04	125	mS/cm	3.38	--	Note (b)	0.3135	No
Hardness, Calcium Carbonate	mg/L	150	81	330	76	130	41	190	63	mg/s	284	1142	208	3673	4823	2835	1728	17313	17313	mg/L	1	None required	GCDWQ (1), Note (a)	127.5	No
pH	pH units	7.85	7.68	7.8	7.98	7.82	6.76	7.87	7.95	pH units	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	pH units	N/A	None	GCDWQ (1)	7.9025	No
Phosphorous	mg/L	0.096	0.065	0.038	0.11	0.092	0.061	0.032	0.12	mg/s	0.18	0.92	0.02	5.32	3.41	4.22	0.29	32.98	32.98	mg/L	0.001	--	Note (f)	-	No
Total Suspended Solids	mg/L	72	46	20	110	< 10	25	< 10	82	mg/s	136	648	13	5316	<371	1728	<91	22535	22535	mg/L	1	--	Note (b)	<1-<10	No
Metals																									
Aluminum	µg/L	1800	990	740	1500	170	970	53	1600	µg/s	3408	13952	466	72496	6307	67060	482	439702	439702	µg/L	15	100	GCDWQ (1)	7.075	No
Antimony	µg/L	0.84	1.4	0.64	0.61	0.51	0.62	< 0.50	0.88	µg/s	1.6	20	0	29.5	18.9	43	<5	242	242	µg/L	0.01	6	GCDWQ (1)	<0.5	No
Arsenic	µg/L	< 1.0	< 1.0	< 1.0	<1.0	< 1.0	< 1.0	< 1.0	<1.0	µg/s	<2	<14	<1	<48	<37	<69	<9	<275	< 275	µg/L	<0.01	10	GCDWQ (1)	<1	No
Barium	µg/L	50	20	73	35	29	9.3	32	41	µg/s	95	282	46	1692	1076	643	291	11267	11267	µg/L	0	1000	ODWS (2)	22.25	No
Beryllium	µg/L	< 0.50	< 0.50	< 0.50	<0.50	< 0.50	< 0.50	< 0.50	<0.50	µg/s	<0.9	<7.0	<0.3	<24.2	<18.6	<34.6	<4.5	<137.4	< 137	µg/L	<0.00	4	MECP GW1 (3)	<0.5	No
Bismuth	µg/L	< 1.0	< 1.0	< 1.0	<1.0	< 1.0	< 1.0	< 1.0	<1.0	µg/s	<2	<14	<1	<48	<37	<69	<9	<275	< 275	µg/L	<0.01	<1	LWC-1 Bkgrd	<1	No
Boron	µg/L	48	11	35	<10	41	< 10	43	13	µg/s	91	155	22	<483	1521	<691	391	3573	3573	µg/L	0.1	5000	GCDWQ (1)	25.5	No
Cadmium	µg/L	< 0.10	< 0.10	< 0.10	<0.10	< 0.10	< 0.10	< 0.10	<0.10	µg/s	<0.2	<1.4	<0.1	<4.8	<3.7	<6.9	<0.9	<27.5	< 27.5	µg/L	<0.001	5	ODWS (2)	0.0095	No
Calcium	µg/L	65000	34000	100000	66000	41000	16000	54000	47000	µg/s	123050	479153	63028	3189817	1521119	1106148	491228	12916253	12916253	µg/L	438	None required	GCDWQ (1)	34000	No
Chromium	µg/L	< 5.0	< 5.0	< 5.0	8.7	< 5.0	< 5.0	< 5.0	5.2	µg/s	<9	<70	<3	420	<186	<346	<45	1429	1429	µg/L	0.0	50	GCDWQ (1)	<5	No
Cobalt	µg/L	1	< 0.50	0.57	1.2	< 0.50	< 0.50	< 0.50	1.1	µg/s	2	<7.0	0.36	58	<18.6	<34.6	<4.5	302	302	µg/L	0.010	3	MECP GW1 (3)	<0.5	No
Copper	µg/L	18	4.3	3.9	8	7.6	3.2	2.4	6.2	µg/s	34	61	2	387	282	221	22	1704	1704	µg/L	0.1	1000	MECP GW1 (3)	<1	No
Iron	µg/L	1800	1200	760	3100	310	720	< 100	1900	µg/s	3408	16911	479	149825	11501	49777	<910	522146	522146	µg/L	18	300	GCDWQ (1), Note (e)	<100	No
Lead	µg/L	3.8	2.8	1.1	6.2	0.55	1.6	< 0.50	4	µg/s	7	39	1	300	20.4	111	<4.5	1099	1099	µg/L	0.0	10	ODWS (2)	<0.5	No
Lithium	µg/L	5.6	< 5.0	5.2	<5.0	< 5.0	< 5.0	< 5.0	5.1	µg/s	11	<70	3	<242	<186	<346	<45	1402	1402	µg/L	0.0	<5	LWC-1 Bkgrd	<5	No
Magnesium	µg/L	7200	3100	16000	4500	6100	1300	9400	3500	µg/s	13630	43688	10084	217488	226313	89874	85510	961849	961849	µg/L	33	None required	GCDWQ (1)	8775	No
Manganese	µg/L	170	56	220	200	66	30	27	81	µg/s	322	789	139	9666	2449	2074	246	22260	22260	µg/L	1	50	MECP GW1 (3)	<2	No
Mercury (filtered)	µg/L	< 0.01	< 0.01	< 0.01	<0.01	< 0.01	< 0.01	< 0.01	<0.01	µg/s	<0.02	<0.14	<0.01	<0.48	<0.37	<0.69	<0.09	<2.75	< 2.75	µg/L	<0.0001	1	GCDWQ (1)	0.01	No
Molybdenum	µg/L	1.8	0.56	1.9	0.8	1.2	< 0.50	1.8	0.58	µg/s	3.4	7.9	1.2	38.7	44.5	<34.6	16.4	159.4	159	µg/L	0.01	70	MECP GW1 (3)	1.3	No
Nickel	µg/L	3	1.8	1.5	4.2	1.4	1.6	< 1.0	3	µg/s	6	25	1	203	52	111	<9	824	824	µg/L	0.03	100	MECP GW1 (3)	1.025	No
Potassium	µg/L	3200	1700	3400	2300	2500	1100	2200	2400	µg/s	6058	23958	2143	111160	92751	76048	20013	659553	659553	µg/L	22	--	Note (c)	1625	No
Selenium	µg/L	< 2.0	< 2.0	< 2.0	<2.0	< 2.0	< 2.0	< 2.0	<2.0	µg/s	<4	<28	<1	<97	<74	<138	<18	<550	< 550	µg/L	<0.02	10	ODWS (2)	0.13875	No
Silicon	µg/L	5000	2300	3800	4400	1100	2000	930	7600	µg/s	9465	32413	2395	212654	40811	138268	8460	2088586	2088586	µg/L	71	--	Note (d)	260	No
Silver	µg/L	< 0.10	< 0.10	< 0.10	<0.10	< 0.10	< 0.10	< 0.10	<0.10	µg/s	<0.2	<1.4	<0.1	<4.8	<3.7	<6.9	<0.9	<27.5	< 27.5	µg/L	<0.001	none required	GCDWQ (1)	<0.1	No
Sodium	µg/L	400000	71000	540000	130000	220000	11000	250000	59000	µg/s	757230	1000585	340351	6282972	8162100	760476	2274204	16214019	16214019	µg/L	550	≤200	GCDWQ (1), Note (e)	14500	No
Strontium	µg/L	400	160	680	230	660	110	1000	360	µg/s	757	2255	429	11116	24486	7605	9097	98933	98933	µg/L	3	7	GCDWQ (1)	180	No
Tellurium	µg/L	< 1.0	< 1.0	< 1.0	<1.0	< 1.0	< 1.0	< 1.0	<1.0	µg/s	<2	<14	<1	<48	<37	<69	<9	<275	< 275	µg/L	<0.01	<1	LWC-1 Bkgrd	<1	No
Thallium	µg/L	< 0.050	< 0.050	< 0.050	<0.050	< 0.050	< 0.050	< 0.050	<0.050	µg/s	<0.09	<0.70	<0.03	<2.42	<1.86	<3.46	<0.45	<13.74	< 13.74	µg/L	<0.000	<0.05	LWC-1 Bkgrd	<0.05	No
Tin	µg/L	< 1.0	< 1.0	< 1.0	<1.0	< 1.0	< 1.0	< 1.0	<1.0	µg/s	<2	<14	<1	<48	<37	<69	<9	<275	< 275	µg/L	<0.01	<1	LWC-1 Bkgrd	<1	No
Titanium	µg/L	66	38	13	53	6.2	26	< 5.0	43	µg/s	125	536	8	2562	230	1797	<45	11817	11817	µg/L	0	<5	LWC-1 Bkgrd	<5	No
Tungsten	µg/L	< 1.0	< 1.0	< 1.0	<1.0	< 1.0	< 1.0	< 1.0	<1.0	µg/s	<2	<14	<1	<48	<37	<69	<9	<275	< 275	µg/L	<0.01	<1	LWC-1 Bkgrd	<1	No
Uranium	µg/L	0.3	0.19	0.78	0.27	0.17	< 0.10	0.64	0.6	µg/s	0.6	2.7	0.5	13.0	6.3	6.9	<0.9	164.9	165	µg/L	0.01	20	GCDWQ (1)	0.3675	No
Vanadium	µg/L	5.1	2.6	1.7	5	1	1.6	< 0.50	4.8	µg/s	10	37	1	242	37	111	<4.5	1319	1319	µg/L	0.0	6.2	MECP GW1 (3)	<0.5	No
Zinc	µg/L	100	91	99	190	69	38	61	72	µg/s	189	1282	62	9183	2560	2627	555	19787	19787	µg/L	1	≤5	GCDWQ (1), Note (e)	<5	No
Zirconium	µg/L	1.2	< 1.0	< 1.0	1.1	< 1.0	< 1.0	< 1.0	2.7	µg/s	2	<14	<1	53	<37	<69	<9	742	742	µg/L	0.03	<1	LWC-1 Bkgrd	<1	No

Table A.4c: Screening of Storm Water COPCs for Human Health - Lake Water East

Location	Units	Concentration: Catchment 10				Concentration: Catchment 13				Units	Loading: Catchment 10				Loading: Catchment 13				Max Loading	Units	Screening: Final Concentration in Lake	Screening Criteria: Selected Screening Level	Screening Criteria: Source / Basis	Mean Background in 2015 (LWC-1)	Carried Forward as COPC for the HHRA?
Station ID		M2-1				M5-1					M2-1				M5-1										
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		20-Aug-15	28-Oct-15	19-Nov-15	11-Jun-16	20-Aug-15	28-Oct-15	19-Nov-15	11-Jun-16							
Petroleum Hydrocarbons (and BTEX)																									
Benzene	µg/L	< 0.20	< 0.20	< 0.20	<0.20	< 0.20	< 0.20	< 0.20	<0.20	µg/s	<0.4	<2.8	<0.1	<9.7	<7.4	<13.8	<1.8	<55.0	< 55	µg/L	<0.002	5	GCDWQ (1)	-	No
Toluene	µg/L	0.44	< 0.20	< 0.20	<0.20	0.44	< 0.20	< 0.20	<0.20	µg/s	0.8	<2.8	<0.1	<9.7	16.3	<13.8	<1.8	<55.0	< 55	µg/L	<0.002	60	GCDWQ (1)	-	No
Ethylbenzene	µg/L	< 0.20	< 0.20	< 0.20	<0.20	< 0.20	< 0.20	< 0.20	<0.20	µg/s	<0.4	<2.8	<0.1	<9.7	<7.4	<13.8	<1.8	<55.0	< 55	µg/L	<0.002	140	GCDWQ (1)	-	No
o-Xylene	µg/L	< 0.20	< 0.20	< 0.20	<0.20	< 0.20	< 0.20	< 0.20	<0.20	µg/s	<0.4	<2.8	<0.1	<9.7	<7.4	<13.8	<1.8	<55.0	< 55	µg/L	<0.002	--	See total xylenes	-	No
m,p-Xylenes	µg/L	< 0.40	< 0.40	< 0.40	<0.40	< 0.40	< 0.40	< 0.40	<0.40	µg/s	<0.8	<5.6	<0.3	<19.3	<14.8	<27.7	<3.6	<109.9	< 109.9	µg/L	<0.00	--	See total xylenes	-	No
Xylenes, Total	µg/L	< 0.40	< 0.40	< 0.40	<0.40	< 0.40	< 0.40	< 0.40	<0.40	µg/s	<0.8	<5.6	<0.3	<19.3	<14.8	<27.7	<3.6	<109.9	< 109.9	µg/L	<0.00	90	GCDWQ (1)	-	No
Petroleum Hydrocarbons - F1 (C6-C10)-BTEX	µg/L	< 25	< 25	< 25	<25	< 25	< 25	< 25	<25	µg/s	<47	<352	<16	<1208	<928	<1728	<227	<6870	< 6870	µg/L	<0.2	820	MECP GW1 (3)	<25	No
Petroleum Hydrocarbons - F1 (C6-C10)	µg/L	< 25	< 25	< 25	<25	< 25	< 25	< 25	<25	µg/s	<47	<352	<16	<1208	<928	<1728	<227	<6870	< 6870	µg/L	<0.2	820	MECP GW1 (3)	<25	No
Petroleum Hydrocarbons - F2 (C10-C16)	µg/L	< 100	< 100	< 100	<100	< 100	< 100	< 100	<100	µg/s	<189	<1409	<63	<4833	<3710	<6913	<910	<27481	< 27481	µg/L	<1	300	MECP GW1 (3)	<100	No
Petroleum Hydrocarbons - F3 (C16-C34)	µg/L	< 200	< 200	< 200	<200	< 200	< 200	< 200	<200	µg/s	<379	<2819	<126	<9666	<7420	<13827	<1819	<54963	< 54963	µg/L	<2	1000	MECP GW1 (3)	<200	No
Petroleum Hydrocarbons - F4 (C34-C50)	µg/L	< 200	< 200	< 200	<200	< 200	< 200	< 200	<200	µg/s	<379	<2819	<126	<9666	<7420	<13827	<1819	<54963	< 54963	µg/L	<2	1100	MECP GW1 (3)	<200	No
Radiological																									
Carbon-14	Bq/L	< 20	< 20	< 20	<20	< 20	< 20	< 20	<20	Bq/s	<38	<282	<13	<967	<742	<1383	<182	<5496	< 5496	Bq/L	<0.2	200	ODWS (2)	<0.1	No
Cesium-134	Bq/L	< 1	< 1	< 1	<1	< 1	< 1	< 1	<1	Bq/s	<2	<14	<1	<48	<37	<69	<9	<275	< 275	Bq/L	<0.01	7	ODWS (2)	<0.1	No
Cesium-137	Bq/L	< 1	< 1	< 1	<1	< 1	< 1	< 1	<1	Bq/s	<2	<14	<1	<48	<37	<69	<9	<275	< 275	Bq/L	<0.01	10	GCDWQ (1)	<0.1	No
Cobalt-60	Bq/L	-	< 1	< 1	<1	-	< 1	< 1	<1	Bq/s	-	<14	<1	<48	-	<69	<9	<275	< 275	Bq/L	<0.01	2	ODWS (2)	<0.1	No
Iodine-131	Bq/L	< 1	< 1	< 1	<1	< 1	< 1	< 1	<1	Bq/s	<2	<14	<1	<48	<37	<69	<9	<275	< 275	Bq/L	<0.01	6	ODWS (2)	-	No
Manganese-54	Bq/L	< 1	-	-	-	< 1	-	-	-	Bq/s	<2	-	-	-	<37	-	-	-	< 37	Bq/L	<0.0013	200	ODWS (2)	-	No
Tritium (Hydrogen-3)	Bq/L	227	41	222	53	158	< 15	111	<15	Bq/s	430	578	140	2562	5862	<1037	1010	<4122	5862	Bq/L	0.2	7000	GCDWQ (1)	<4.4	No
Zinc-65	Bq/L	< 1	-	-	-	< 1	-	-	-	Bq/s	<2	-	-	-	<37	-	-	-	< 37	Bq/L	<0.0013	40	ODWS (2)	-	No

Notes:

a - Hardness is dependent on local, naturally occurring conditions; no guideline is required under the GCDWQ. Likewise, no screening levels have been selected for hardness and hardness-related parameters (e.g. alkalinity)

b - Risk-based guidelines are not applicable to water quality parameters such as conductivity, temperature, biological oxygen demand, chemical oxygen demand, and total suspended solids and therefore are excluded from screening.

c - Potassium is an essential electrolyte in the human body and is not applicable for screening of risk to human health.

d - There are no human health risk-based guidelines for silicon. Silicon is an abundant element in the earth's crust and has not been shown to have adverse effects on human health.

e - Zinc, iron and chloride are considered non-toxic at levels found in drinking water, the GCDWQ is based on aesthetic objectives (taste, staining). Aesthetic objective for sodium is based on guidelines for persons with sodium-reduced diets.

f - Phosphorus in drinking water is not harmful to human health; and is further screened for the ecological risk assessment.

References:

1. Health Canada (HC). 2020. Guidelines for Canadian Drinking Water Quality—Summary Table. Water and Air Quality Bureau, Healthy Environments and Consumer Safety Branch, Health Canada, Ottawa, Ontario. September.
2. Ontario Regulation 169/03: Ontario Drinking Water Quality Standards, made under the Safe Drinking Water Act, 2002
3. Ministry of Environment (MOE) 2011. Rationale for the Development of Soil, Ground Water and Sediment Standards in Ontario Under Part XV.1 of the Environmental Protection Act. GW1 Component Value Protective of Drinking Water

Bold Text	= Final concentration in lake exceeds screening criteria
-	= No data available
--	= No associated screening criteria

Table A.4d: Screening of Stormwater COPCs for Human Health - Lake Water West

Location	Units	Concentration						Unit	Loading						Max Loading	Screening				Mean Background in 2015 (LWC-1)	Carried Forward as COPC for the HHRA?
		Catchment 3							Catchment 3							Units	Final Concentration in Lake	Screening Criteria			
Station ID		MH211							MH211									Selected Screening Level	Source / Basis		
Date		20-Aug-15	28-Oct-15	19-Nov-15	20-Aug-15	11-Jun-16	2016-06-11 (dup)		20-Aug-15	28-Oct-15	19-Nov-15	20-Aug-15	11-Jun-16	2016-06-11 (Dup)							
General																					
Chloride	mg/L	22	2.1	36	22	2.6	2.4	mg/s	380	74	361	377	333	307	380	mg/L	0.02	250	AO	-	No
Conductivity	mS/cm	0.225	0.073	0.314	0.225	0.063	0.064	mS/cm	N/A	N/A	N/A	N/A	N/A	N/A	< -	mS/cm	N/A	--	Note (b)	0.3135	No
Hardness, Calcium Carbonate	mg/L	62	32	89	63	23	23	mg/s	1071	1120	892	1080	2946	2946	2946	mg/L	0.1	None required	GCDWQ (1), Note (a)	127.5	No
pH	pH units	7.6	7.66	7.92	7.55	7.49	7.56	pH units	N/A	N/A	N/A	N/A	N/A	N/A	< -	pH units	7.92	None	GCDWQ (1)	7.9025	No
Phosphorous	mg/L	0.16	0.06	0.083	0.16	0.11	0.11	mg/s	2.76	2.10	0.83	2.7	14	14	14	mg/L	0.0006	--	Note (f)	-	No
Total Suspended Solids	mg/L	40	11	< 10	34	<10	<10	mg/s	691	385	<100	583	<1281	<1281	< 1281	mg/L	<0.05	--	Note (b)	<1-<10	No
Metals																					
Aluminum	µg/L	550	160	130	570	120	100	µg/s	9499	5602	1304	9773	15371	12809	15371	µg/L	1	100	GCDWQ (1)	7.075	No
Antimony	µg/L	3.7	0.9	1.5	3.6	0.76	0.94	µg/s	64	32	15	62	97	120	120	µg/L	0.01	6	GCDWQ (1)	<0.5	No
Arsenic	µg/L	< 1.0	< 1.0	< 1.0	< 1.0	<1.0	<1.0	µg/s	<17	<35	<10	<17	<128	<128	< 128	µg/L	<0.005	10	GCDWQ (1)	<1	No
Barium	µg/L	24	8.4	26	23	4.8	4.2	µg/s	414	294	261	394	615	538	615	µg/L	0.03	1000	ODWS (2)	22.25	No
Beryllium	µg/L	< 0.50	< 0.50	< 0.50	< 0.50	<0.50	<0.50	µg/s	<8.6	<17.5	<5.0	<8.6	<64.0	<64.0	< 64	µg/L	<0.003	4	MECP GW1 (3)	<0.5	No
Bismuth	µg/L	< 1.0	< 1.0	< 1.0	< 1.0	<1.0	<1.0	µg/s	<17	<35	<10	<17	<128	<128	< 128	µg/L	<0.005	<1	LWC-1 Bkgrd	<1	No
Boron	µg/L	29	< 10	14	28	<10	<10	µg/s	501	<350	140	480	<1281	<1281	< 1281	µg/L	<0.05	5000	GCDWQ (1)	25.5	No
Cadmium	µg/L	0.69	0.23	0.15	0.87	0.21	0.2	µg/s	12	8.1	1.5	15	27	26	27	µg/L	0.001	5	ODWS (2)	0.0095	No
Calcium	µg/L	27000	11000	32000	27000	8500	8600	µg/s	466310	385165	320868	462953	1088796	1101605	1101605	µg/L	47	None required	GCDWQ (1)	34000	No
Chromium	µg/L	< 5.0	< 5.0	< 5.0	< 5.0	<5.0	<5.0	µg/s	<86	<175	<50	<86	<640	<640	< 640	µg/L	<0.03	50	GCDWQ (1)	<5	No
Cobalt	µg/L	0.73	< 0.50	< 0.50	0.72	<0.50	<0.50	µg/s	12.6	<18	<5	12	<64	<64	< 64	µg/L	<0.003	3	MECP GW1 (3)	<0.5	No
Copper	µg/L	43	12	11	42	7.6	6.9	µg/s	743	420	110	720	974	884	974	µg/L	0.04	1000	MECP GW1 (3)	<1	No
Iron	µg/L	790	280	220	800	160	120	µg/s	13644	9804	2206	13717	20495	15371	20495	µg/L	1	300	GCDWQ (1), Note (e)	<100	No
Lead	µg/L	4.9	2.2	1.1	5.1	1.3	1.3	µg/s	85	77	11	87	167	167	167	µg/L	0.01	10	ODWS (2)	<0.5	No
Lithium	µg/L	< 5.0	< 5.0	< 5.0	< 5.0	<5.0	<5.0	µg/s	<86	<175	<50	<86	<640	<640	< 640	µg/L	<0.03	<5	LWC-1 Bkgrd	<5	No
Magnesium	µg/L	2200	690	2100	2300	520	480	µg/s	37996	24160	21057	39437	66609	61485	66609	µg/L	3	None required	GCDWQ (1)	8775	No
Manganese	µg/L	42	15	20	41	11	11	µg/s	725	525	201	703	1409	1409	1409	µg/L	0.06	50	MECP GW1 (3)	<2	No
Mercury (filtered)	µg/L	< 0.01	< 0.01	0.01	< 0.01	<0.01	<0.01	µg/s	<0.17	<0.35	<0.10	<0.17	<1	<1	< 1.00	µg/L	<0.00004	1	GCDWQ (1)	0.01	No
Molybdenum	µg/L	0.99	< 0.50	0.85	1	<0.50	<0.50	µg/s	17	<18	9	17	<64	<64	< 64	µg/L	<0.003	70	MECP GW1 (3)	1.3	No
Nickel	µg/L	2.9	< 1.0	1	2.7	<1.0	<1.0	µg/s	50	<35	10	46	<128	<128	< 128	µg/L	<0.005	100	MECP GW1 (3)	1.025	No
Potassium	µg/L	2200	750	1800	2200	1100	1100	µg/s	37996	26261	18049	37722	140903	140903	140903	µg/L	6	--	Note (c)	1625	No
Selenium	µg/L	< 2.0	< 2.0	< 2.0	< 2.0	<2.0	<2.0	µg/s	<35	<70	<20	<34	<256	<256	< 256	µg/L	<0.01	10	ODWS (2)	0.13875	No
Silicon	µg/L	2100	590	2000	2000	470	450	µg/s	36269	20659	20054	34293	60204	57642	60204	µg/L	3	--	Note (d)	260	No
Silver	µg/L	< 0.10	< 0.10	< 0.10	0.17	<0.10	<0.10	µg/s	<1.7	<3.5	<1.0	2.9	<13	<13	< 13	µg/L	<0.0006	none required	GCDWQ (1)	<0.1	No
Sodium	µg/L	20000	2000	29000	20000	2200	2200	µg/s	345415	70030	290787	342928	281806	281806	345415	µg/L	15	≤200	GCDWQ (1), Note (e)	14500	No
Strontium	µg/L	110	30	120	110	24	24	µg/s	1900	1050	1203	1886	3074	3074	3074	µg/L	0.1	7	GCDWQ (1)	180	No
Tellurium	µg/L	< 1.0	< 1.0	< 1.0	< 1.0	<1.0	<1.0	µg/s	<17.3	<35.0	<10.0	<17.1	<128	<128	< 128	µg/L	<0.005	<1	LWC-1 Bkgrd	<1	No
Thallium	µg/L	< 0.050	< 0.050	< 0.050	< 0.050	<0.050	<0.050	µg/s	<0.86	<1.75	<0.50	<0.9	<6	<6	< 6	µg/L	<0.0003	<0.05	LWC-1 Bkgrd	<0.05	No
Tin	µg/L	< 1.0	< 1.0	< 1.0	< 1.0	<1.0	<1.0	µg/s	<17	<35	<10	<17	<128	<128	< 128	µg/L	<0.005	<1	LWC-1 Bkgrd	<1	No
Titanium	µg/L	18	6.8	5	17	6.5	<5.0	µg/s	311	238	50	291	833	<640	833	µg/L	0.04	<5	LWC-1 Bkgrd	<5	No
Tungsten	µg/L	< 1.0	< 1.0	< 1.0	< 1.0	<1.0	<1.0	µg/s	<17	<35	<10	<17	<128	<128	< 128	µg/L	<0.005	<1	LWC-1 Bkgrd	<1	No
Uranium	µg/L	0.13	< 0.10	0.34	0.14	0.1	<0.10	µg/s	2.2	<3.5	3.4	2.4	12.8	<12.8	13	µg/L	0.0005	20	GCDWQ (1)	0.3675	No
Vanadium	µg/L	2.8	1	1.2	2.9	0.88	0.71	µg/s	48	35	12	50	113	91	113	µg/L	0.005	6.2	MECP GW1 (3)	<0.5	No
Zinc	µg/L	510	220	150	510	160	160	µg/s	8808	7703	1504	8745	20495	20495	20495	µg/L	1	≤5	GCDWQ (1), Note (e)	<5	No
Zirconium	µg/L	< 1.0	< 1.0	< 1.0	< 1.0	<1.0	<1.0	µg/s	<17	<35	<10	<10	<128	<128	< 128	µg/L	<0.005	<1	LWC-1 Bkgrd	<1	No

Table A.4d: Screening of Stormwater COPCs for Human Health - Lake Water West

		Concentration						Loading								Screening					
Location	Units	Catchment 3						Unit	Catchment 3						Max Loading	Units	Final Concentration in Lake	Screening Criteria		Mean Background in 2015 (LWC-1)	Carried Forward as COPC for the HHRA?
Station ID		MH211							MH211									Selected Screening Level	Source / Basis		
Date		20-Aug-15	28-Oct-15	19-Nov-15	20-Aug-15	11-Jun-16	2016-06-11 (dup)		20-Aug-15	28-Oct-15	19-Nov-15	20-Aug-15	11-Jun-16	2016-06-11 (Dup)							
Petroleum Hydrocarbons (and BTEX)																					
Benzene	µg/L	< 0.20	< 0.20	< 0.20	< 0.20	<0.20	<0.20	µg/s	<3.5	<7.0	<2.0	<3.4	<25.6	<25.6	< 25.6	µg/L	<0.001	5	GCDWQ (1)	-	No
Toluene	µg/L	0.22	< 0.20	< 0.20	0.21	<0.20	<0.20	µg/s	3.8	<7.0	<2.0	3.6	<25.6	<25.6	< 25.6	µg/L	<0.001	60	GCDWQ (1)	-	No
Ethylbenzene	µg/L	< 0.20	< 0.20	< 0.20	< 0.20	0.49	0.41	µg/s	<3.5	<7.0	<2.0	<3.4	63	53	62.8	µg/L	0.003	140	GCDWQ (1)	-	No
o-Xylene	µg/L	0.36	< 0.20	< 0.20	0.38	0.7	0.66	µg/s	6.2	<7.0	<2.0	7	90	85	90	µg/L	0.004	--	See total xylenes	-	No
m,p-Xylenes	µg/L	0.56	< 0.40	< 0.40	0.55	1.5	1.6	µg/s	9.7	<14.0	<4.0	9	192	205	205	µg/L	0.01	--	See total xylenes	-	No
Xylenes, Total	µg/L	0.92	< 0.40	< 0.40	0.94	2.2	2.3	µg/s	15.9	<14.0	<4.0	16	282	295	295	µg/L	0.01	90	GCDWQ (1)	-	No
Petroleum Hydrocarbons - F1 (C6-C10)-BTEX	µg/L	< 25	< 25	< 25	< 25	<25	<25	µg/s	<432	<875	<251	<429	<3202	<3202	< 3202	µg/L	<0.1	820	MECP GW1 (3)	<25	No
Petroleum Hydrocarbons - F1 (C6-C10)	µg/L	< 25	< 25	< 25	< 25	<25	<25	µg/s	<432	<875	<251	<429	<3202	<3202	< 3202	µg/L	<0.1	820	MECP GW1 (3)	<25	No
Petroleum Hydrocarbons - F2 (C10-C16)	µg/L	< 100	< 100	< 100	< 100	<100	<100	µg/s	<1727	<3501	<1003	<1715	<12809	<12809	< 12809	µg/L	<0.5	300	MECP GW1 (3)	<100	No
Petroleum Hydrocarbons - F3 (C16-C34)	µg/L	210	< 200	< 200	230	<200	<200	µg/s	3627	<7003	<2005	<3429	<25619	<25619	< 25619	µg/L	<1	1000	MECP GW1 (3)	<200	No
Petroleum Hydrocarbons - F4 (C34-C50)	µg/L	< 200	< 200	< 200	< 200	<200	<200	µg/s	<3454	<7003	<2005	<3429	<25619	<25619	< 25619	µg/L	<1	1100	MECP GW1 (3)	<200	No
Radiological																					
Carbon-14	Bq/L	< 20	< 20	< 20	< 20	<20	<20	Bq/s	<345	<700	<201	<343	<2562	<2562	< 2562	Bq/L	<0.1	200	ODWS (2)	<0.1	No
Cesium-134	Bq/L	< 1	< 1	< 1	< 1	<1	<1	Bq/s	<17	<35	<10	<17	<128	<128	< 128	Bq/L	<0.005	7	ODWS (2)	<0.1	No
Cesium-137	Bq/L	< 1	< 1	< 1	< 1	<1	<1	Bq/s	<17	<35	<10	<17	<128	<128	< 128	Bq/L	<0.005	10	GCDWQ (1)	<0.1	No
Cobalt-60	Bq/L	-	< 1	< 1	-	<1	<1	Bq/s	-	<35	<10	-	<128	<128	< 128	Bq/L	<0.005	2	ODWS (2)	<0.1	No
Iodine-131	Bq/L	< 1	< 1	< 1	< 1	<1	<1	Bq/s	<17	<35	<10	<17	<128	<128	< 128	Bq/L	<0.005	6	ODWS (2)	-	No
Manganese-54	Bq/L	< 1	-	-	< 1	-	-	Bq/s	<17	-	-	<17	-	-	< 17	Bq/L	<0.0007	200	ODWS (2)	-	No
Tritium (HTO)	Bq/L	3520	7080	39600	3480	2930	2930	Bq/s	60793	247906	397074	59669	375314	375314	397074.269	Bq/L	17	7000	GCDWQ (1)	<4.4	No
Zinc-65	Bq/L	< 1	-	-	< 1	-	-	Bq/s	<17	-	-	<17	-	-	< 17	Bq/L	<0.0007	40	ODWS (2)	-	No

Notes:

a - Hardness is dependent on local, naturally occurring conditions; no guideline is required under the GCDWQ. Likewise, no screening levels have been selected for hardness and hardness-related parameters (e.g. alkalinity)

b - Risk-based guidelines are not applicable to water quality parameters such as conductivity, temperature, biological oxygen demand, chemical oxygen demand, and total suspended solids and therefore are excluded from screening.

c - Potassium is an essential electrolyte in the human body and is not applicable for screening of risk to human health.

d - There are no human health risk-based guidelines for silicon. Silicon is an abundant element in the earth's crust and has not been shown to have adverse effects on human health.

e - Zinc, iron and chloride are considered non-toxic at levels found in drinking water, the GCDWQ is based on aesthetic objectives (taste, staining). Aesthetic objective for sodium is based on guidelines for persons with sodium-reduced diets.

f - Phosphorus in drinking water is not harmful to human health; and is further screened for the ecological risk assessment.

References:

1. Health Canada (HC). 2020. Guidelines for Canadian Drinking Water Quality—Summary Table. Water and Air Quality Bureau, Healthy Environments and Consumer Safety Branch, Health Canada, Ottawa, Ontario. September.

2. Ontario Regulation 169/03: Ontario Drinking Water Quality Standards, made under the Safe Drinking Water Act, 2002

3. Ministry of Environment (MOE) 2011. Rationale for the Development of Soil, Ground Water and Sediment Standards in Ontario Under Part XV.1 of the Environmental Protection Act. GW1 Component Value Protective of Drinking Water

Bold Text	= Final concentration in lake exceeds screening criteria
-	= No data available
--	= No associated screening criteria

Table A.5: Non-Radiological Screening of Air COPCs for Ecological Health

Contaminant	CAS No.	Averaging Period	Maximum POI Concentration (µg/m³)						Screening Criteria			Carried Forward as COPC for the EcoRA?
			2016[a]	2017[b]	2018[c]	2019[d]	2020[e]	2016-2020 Maximum	Selected Value (µg/m³)	Source / Basis	Limiting Effect	
2-(2-aminoethoxy) ethanol	929-06-6	0.5hr	0.549	0.49	-	-	-	0.549	380	TCEQ Short-Term ESL	Health	No
		24hr	-	-	0.11	0.11	0.12	0.36 (adj from 24h to 0.5h)				
Acetic Acid	64-19-7	0.5hr	3.33	2.5	-	-	-	3.33	250	TCEQ Short-Term ESL	Health	No
Acetone	67-64-1	0.5hr	0.335	-	-	-	-	0.335	11880	Ontario AAQC (24h)	Health	No
Ammonia	7664-41-7	0.5hr	212	172	-	-	-	72 (adj. from 0.5h to 24h)	100	Ontario AAQC (24h)	Health	No
		24hr	-	-	8	8	9	9				
Ammonium Hydroxide	1336-21-6	0.5hr	0.0213	-	-	-	-	0.0213	180	TCEQ Short-Term ESL	Health	No
Amyl Alcohol	71-41-0	0.5hr	0.00107	-	-	-	-	0.00107	73	TCEQ Long-Term ESL (annual)	Health	No
Benzo(a)pyrene	50-32-8	0.5hr	-	0.00013	-	-	-	0.00013	0.00005	Ontario AAQC (24h)	Health	No
		24hr	-	-	0.000026	0.000026	0.000029	0.000029				
		Annual	-	-	0.00000056	0.00000056	0.00000047	0.00000056	0.00001	Ontario AAQC (annual)	Health	
Cadmium	7440-43-9	0.5hr	-	0.00081	-	-	-	0.00081	0.025	Ontario AAQC (24h)	Health	No
Carbon dioxide	124-38-9	0.5hr	-	32123	-	-	-	32123	N/A	Major component of Air	N/A	No
		24hr	-	-	12268	12268	13598	13598				
Carbon monoxide	630-08-0	0.5hr	145	-	-	-	-	145	36200	Ontario AAQC (1h)	Health	No
Chromium VI	7440-47-3VI	0.5hr	-	0.00051	-	-	-	0.00017 (adj. from 0.5h to 24h)	0.0004	Ontario AAQC (24h)	Health	No
		24hr	-	-	0.00011	0.00011	0.00012	0.00012				
		Annual	-	-	0.0000017	0.0000017	0.0000015	0.0000017	0.00007	Ontario AAQC	Health	
Cobalt	7440-48-4	0.5hr	-	0.0028	-	-	-	0.0028	0.1	Ontario AAQC (24h)	Health	No
		24hr	-	-	0.0026	0.0026	0.0029	0.0029				
Deuterium	7782-39-0	0.5hr	0.00000316	-	-	-	-	0.00000316	0.3	*De minimus level*	--	No
Ethanolamine	141-43-5	0.5hr	11	9.3	-	-	-	11	97	TCEQ Short-Term ESL	Health	No
		24hr	-	-	2.02	2.02	2.27	2.27	33	Adjusted from TCEQ Short-Term ESL	Health	
Ethylene	74-85-1	0.5hr	0.951	0.77	-	-	-	0.951	1400	TCEQ Short-Term ESL	Vegetation	No
Fluoride	7664-39-3	0.5hr	-	0.018	-	-	-	0.018	1.72	Ontario AAQC (24h)	Vegetation (growing season)	No
		24hr	-	-	0.02	0.02	0.02	0.02	1.72	Ontario AAQC	Vegetation (growing season)	
		30day	-	-	0.0048	0.0048	0.0015	0.0048	0.69	Ontario AAQC	Vegetation (growing season)	
Formic Acid	64-18-6	0.5hr	2.39	-	-	-	-	2.39	500	Ontario AAQC (24h)	Health	No
Glycolic Acid	79-14-1	0.5hr	0.0888	-	-	-	-	0.0888	250	TCEQ Short-Term ESL	Health	No
Fuel Oil No. 2	68476-30-2	0.5hr	2.79	1.28	-	-	-	2.79	1000	TCEQ Short-Term ESL	Health	No
Hexane	110-54-3	0.5hr	0.0699	-	-	-	-	0.0699	2500	Ontario AAQC (24h)	Health	No
Hydrazine	302-01-2	Annual	0.00018	0.00033	0.00024	0.00024	0.00023	0.00033	6	EC/HC, 2011 [k]	Health	No
Hydrogen Chloride	7647-01-0	0.5hr	0.213	-	-	-	-	0.213	20	Ontario AAQC (24h)	Health	No
Hydroquinone	123-31-9	0.5hr	0.0888	-	-	-	-	0.0888	20	TCEQ Short-Term ESL	Health	No
Isopropyl Alcohol	67-63-0	0.5hr	0.0213	-	-	-	-	0.0213	7300	Ontario AAQC (24h)	Health	No
Lead	7439-92-1	24hr	-	-	0.00065	0.00065	0.00072	0.00072	0.5	Ontario AAQC	Health	No
		30day	-	-	0.00019	0.00019	0.000061	0.00019	0.2	Ontario AAQC	Health	
Lubricating Oil	72623-85-9	0.5hr	-	4.3	-	-	-	4.3	1000	TCEQ Short-Term ESL	Health	No
Manganese	7439-96-5	0.5hr	-	0.33	-	-	-	0.33	0.4	Ontario AAQC (24h)	Health	No
Methane	74-82-8	0.5hr	0.0161	-	-	-	-	0.0161	0.3	*De minimus level*	--	No
Methanol	67-56-1	0.5hr	0.671	-	-	-	-	0.671	4000	Ontario AAQC (24h)	Health	No
Methylamine	74-89-5	0.5hr	1.4	0.94	-	-	-	1.4	6.4	TCEQ Long-Term ESL	--	No
		24hr	-	-	0.21	0.21	0.24	0.24	6.4	TCEQ Long-Term ESL	--	No
Methylene Chloride	75-09-2	0.5hr	2.25	-	-	-	-	2.25	44	Ontario AAQC (24h)	Health	No
Mineral Spirits	N/A	0.5hr	0.0213	-	-	-	-	0.0213	3500	TCEQ Short-Term ESL	Health	No
Morpholine	110-91-8	0.5hr	299	253	-	-	-	19.4 (adj. from 0.5h to annual)	40	TCEQ Long-Term ESL (annual)	Health	No
		24hr	-	-	37	37	42	8.1 (adj. from 24h to annual)				
Nickel	7440-02-0	0.5hr	-	0.04	-	-	-	0.04	0.2	Ontario AAQC (24h)	Health	No
		24hr	-	-	0.04	0.04	0.04	0.04				
		Annual	-	-	0.00059	0.00059	0.0005	0.00059	0.04	Ontario AAQC (annual)	Health	
Nitric Acid	7697-37-2	0.5hr	0.107	-	-	-	-	0.107	50	TCEQ Short-Term ESL	Health	No

Table A.5: Non-Radiological Screening of Air COPCs for Ecological Health

Contaminant	CAS No.	Averaging Period	Maximum POI Concentration (µg/m³)						Screening Criteria			Carried Forward as COPC for the EcoRA?
			2016[a]	2017[b]	2018[c]	2019[d]	2020[e]	2016-2020 Maximum	Selected Value (µg/m³)	Source / Basis	Limiting Effect	
Nitrogen oxides (Scenario 1)[f]	10102-44-0	0.5hr	478	125	-	-	-	394 (adj. from 0.5h to 1h)	400	Ontario AAQC (1h)	Health	No
		1hr	-	-	120	120	157	157				
		24hr	-	-	10.3	10.3	14.1	14.1	200	Ontario AAQC(24h)	Health	
Particulate matter	N/A	0.5hr	9.16	3	-	-	-	9.16	27	Ontario AAQC (24h)	Health	No
Phosphoric Acid (as P2O5)	7664-38-2	0.5hr	0.0213	-	-	-	-	0.0213	7	Ontario AAQC (24h)	Health	No
Sod ium hypochlorite	7681-52-9	0.5hr	11.9	2.14	-	-	-	11.9	50	TCEQ Short-Term ESL	Health	No
		24hr	-	-	0.66	0.66	0.71	0.71	17	Adjusted from TCEQ Short-Term ESL	Health	
Sulphur dioxide	7446-09-05	0.5hr	333	10.7	-	-	-	**21.6 (adj. from 0.5 to annual)**	11	Ontario AAQC (annual)	Vegetation	**Yes**
		1hr	-	-	22.8	22.8	23.9	1.88 (adj. from 1h to annual)				
		24hr	-	-	2.82	2.82	2.97	0.57 (adj. from 24h to annual)				
Sulphur Hexafluoride	2551-62-4	0.5hr	0.0345	-	-	-	-	0.0345	600000	Ontario AAQC (24 h)	Health	No
Sulphuric Acid	7664-93-9	0.5hr	0.0853	-	-	-	-	0.0853	5	Ontario AAQC (24 h)	Health	No
Toluene	108-88-3	0.5hr	0.000639	-	-	-	-	0.000639	4500	TCEQ Short-Term ESL	Health	No
Total hydrocarbons (Scenerio 1)	N/A	0.5hr	7.07	-	-	-	-	7.07	9.03	Previously approved limit	--	No[g]
Total hydrocarbons (Scenerio 2)	N/A	0.5hr	6.47	-	-	-	-	6.47	9.03	Previously approved limit	--	No[g]
Trimethylbenzene, 1,2,4-	95-63-6	0.5hr	29.4	-	-	-	-	29.4	220	Ontario AAQC (24 h)	Health	No
Xylenes	1330-20-7	0.5hr	0.00213	-	-	-	-	0.00213	2200	TECQ Short-Term ESL	Health	No

Notes:

POI = Point of Impingement

N/A = not applicable

Ontario AAQC = Ontario Ambient Air Quality Criteria (May 1, 2020)

TCEQ ESLs = Texas Commission on Environmental Quality Effects Screening Levels. Short-Term ESLs are used to evaluate 1/2 hour to 1-hour reported air concentrations, and long-term ESLs are used to evaluate annual average concentrations

EC/HC = Screening Assessment for the Challenge, Hydrazine. January, prepared by EC/HC, 2011

Italic Text	= Maximum POI concentration was converted from the averaging period used in the dispersion model to the averaging period set by the available risk-based guideline/standard as per Section 17 of O. Reg. 419/05.
Bold Text	= Maximum POI concentration over the 2016-2020 period exceeds screening criteria
-	= Not identified as a significant contaminant for the calendar year.
--	= No associated screening criteria

a - There were no modifications to the facility in 2016 (P-CORR-00541-00722); therefore the 2016 emission summary is based on the 2015 ESDM report (P-REP-00541-00014-R001).

b - 2017 ESDM Report (P-REP-00541-10008 R002)

c - 2018 ESDM Report (P-REP-00541-10013-R000)

d - 2019 ESDM Report (P-REP-00541-10019-R000)

e - 2020 ESDM Report (P-REP-00541-10025-R001)

f - 1 ppb NO_2 = 1.88 µg/m³; 1 ppb SO_2 = 2.62 µg/m³

g - Although the previously approved limit is not an effects-based limit, total hydrocarbons are considered screened out as they are not required to be identified as a significant contaminant from 2017 to 2020.

h - The chronic value of hydrazine (inhalation non-neoplastic LOAEC) was modified by a safety factor of 10 (convert effect to no-effect), and used to screen max POI concentrations

Table A.6: Screening of Non-Radiological Final Station Effluent from Condenser Cooling Water for the Ecological Risk Assessment

Parameters	Unit	PN U1-4 Maximum / Range					PN U5-8 Maximum / Range					2016-2020 Maximum	Screening Criteria		Carried Forward as COPC for the Eco RA?
		2016	2017	2018	2019	2020	2016	2017	2018	2019	2020		Selected Value	Source / Basis	
Unionized Ammonia	mg/L	0.015	0.01	0.01	0.06	0.01	0.013	0.01	0.01	0.011	0.011	0.06	0.019	(1) CEQG	No
Hydrazine	mg/L	0.008	0.009	0.01	0.017	0.009	0.007	0.009	0.005	0.017	0.025	0.025	0.0026	(1) FEQG	**Yes**
Morpholine	mg/L	0.006	0.002	0.003	0.135	0.135	0.047	0.034	0.059	0.01	0.005	0.135	0.004	(2) iPWQO	**Yes**
pH	pH units	7.7-8.4	7.7-8.2	7.8-8.3	7.6-8.7	8.0-8.3	7.9-8.4	7.9-8.4	7.9-8.3	7.9-8.5	7.9-8.5	7.7-8.5	6.5 - 8.5	(1) PWQO	No
Total Residual Chlorine (TRC)	mg/L	0.003	0.005	0.002	0.003	0.005	0.0033	0.0038	0.0038	0.003	0.024	0.024	0.0005	(1) CEQG	**Yes**

Notes:

Bold Text = 2016-2020 maximum exceeds screening criteria

References:

PWQO = Ontario Provincial Water Quality Objectives, MOEE 1994, updated July 1998

iPWQO = Interim Ontario Provincial Water Quality Objectives, MOE 1994, update July 1998

CEQG = Canadian Environmental Quality Guidelines, current to September 2021

FEQG = Federal Environmental Quality Guidelines, current to September 2021

Table A.7: Screening of Non-Radiological Lake Water COPCs for Ecological Health

Parameters	Unit	2015 Lake Water Results		Screening Criteria		Exceeds Screening Criteria?	Carried Forward as COPC for the EcoRA?	Notes
		Mean Background in 2015 (LWC-1)	Maximum Observed Lake Water in 2015	Selected Screening Level (e)	Source / Basis			
General Chemistry								
Alkalinity (Total as CaCO3)	mg/L	93	110	<25% background	(1) PWQO	No	No	-
Ammonia Nitrogen	mg/L	<0.05	<0.05	0.016	(1) CEQG	Yes	No	DL > Screening criteria but parameter was not detected.
Unionized Ammonia, calculated	mg/L	<0.0016	<0.0020	0.019	(1) CEQG	Yes	No	DL > Screening criteria but parameter was not detected.
Biochemical Oxygen Demand, 5 Day	mg/L	2.25	3	--	See note (b)	-	No	-
Chemical Oxygen Demand	mg/L	5.4	8.6	--	See note (b)	-	No	-
Conductivity	ms/cm	0.314	0.5	--	See note (b)	-	No	-
Conductivity, field measured	ms/cm	0.259	0.375	--	See note (b)	-	No	-
Hardness, Calcium Carbonate	mg/L	127.5	160	--	See note (b)	-	No	-
Temperature, field measured	C	12.33	23.11	--	See note (b)	-	No	Evaluated as a physical stressor
Total Suspended Solids	mg/L	<1-<10	6	5 mg/L above bkgrd	(1) CEQG	No	No	-
pH	pH units	7.9025	8.18	6.5 - 8.5	(1) PWQO	No	No	-
pH, field measured	pH units	8.14	8.34	6.5 - 8.5	(1) PWQO	No	No	-
Total Residual Chlorine, field measured	mg/L	<0.0012	<0.0012	0.0005	(1) CEQG	Yes	No	DL > Screening criteria but parameter was not detected.
Metals/Metalloids								
Aluminum	mg/L	0.007	0.033	0.1	(1) CEQG	No	No	-
Aluminum, filtered	mg/L	0.009	<0.0050	0.1	(1) CEQG	No	No	-
Antimony	mg/L	<0.0005	<0.0005	0.02	(2) iPWQO	No	No	-
Arsenic	mg/L	<0.0010	<0.0011	0.005	(1) CEQG	No	No	-
Barium	mg/L	0.02225	0.024	1	(3) BC Working WGG	No	No	Exceeds background by <20%
Beryllium	mg/L	<0.0005	<0.0005	1.1	(1) PWQO	No	No	-
Bismuth	mg/L	<0.001	<0.001	0.02543	(3) Borgmann et al	No	No	-
Boron	mg/L	0.0255	0.028	1.5	(1) CEQG	No	No	-
Cadmium	mg/L	0.0000095	0.000019	0.00016	(1) CEQG	No	No	-
Calcium	mg/L	34	37	11.6	(3) Suter and Tsao	Yes	No	Exceeds background by <20%
Chromium	mg/L	<0.0050	<0.0050	0.0089	(1) PWQO, CEQG	No	No	-
Cobalt	mg/L	<0.0005	<0.0005	0.001	(1) FEQG	No	No	-
Copper	mg/L	<0.0010	0.0088	0.00236	(1) CEQG	**Yes**	**Yes**	**Max > CEQG**
Iron	mg/L	<0.1	<0.1	0.3	(1) PWQO, CEQG	No	No	-
Lead	mg/L	<0.0005	<0.0005	0.0028	(1) FEQG	No	No	-
Lithium	mg/L	<0.005	<0.005	0.014	(3) Suter and Tsao	No	No	-
Magnesium	mg/L	8.775	9	8.2	(3) Suter and Tsao	Yes	No	Exceeds background by <20%
Manganese	mg/L	<0.0020	0.017	0.37	(1) CEQG	No	No	-
Mercury	mg/L	0.00001	0.00001	0.000026	(1) CEQG	No	No	-
Molybdenum	mg/L	0.0013	0.0014	0.073	(1) CEQG	No	No	-
Nickel	mg/L	0.001025	0.0015	0.025	(1) PWQO	No	No	-
Potassium	mg/L	1.625	1.7	5.3	(3) Suter and Tsao	No	No	-
Selenium	mg/L	0.00013875	0.00021	0.001	(1) CEQG	No	No	-
Silicon	mg/L	0.26	0.66	0.26	(4) Background	Yes	No	Widespread element with low intrinsic toxicity (c)
Silver	mg/L	<0.0001	<0.0001	0.0001	(1) PWQO	No	No	-
Sodium	mg/L	14.5	23	68	(3) Suter and Tsao	No	No	-
Strontium	mg/L	0.18	0.19	2.5	(1) FEQG	No	No	-
Tellurium	mg/L	<0.0010	<0.0010	0.01519	(3) Borgmann et al	No	No	-
Thallium	mg/L	<0.000050	<0.000050	0.0008	(1) CEQG	No	No	-
Tin	mg/L	<0.0010	<0.0010	0.073	(3) Suter and Tsao	No	No	-
Titanium	mg/L	<0.005	<0.005	0.1	(3) Borgmann et al	No	No	-
Tungsten	mg/L	<0.0010	<0.0010	0.03	(2) iPWQO	No	No	-
Uranium	mg/L	0.0003675	0.00042	0.015	(1) CEQG	No	No	-
Vanadium	mg/L	<0.0005	0.00059	0.12	(1) FEQG	No	No	-
Zinc	mg/L	<0.0050	0.0062	0.03	(1) PWQO	No	No	-
Zirconium	mg/L	<0.0010	<0.0010	0.004	(2) iPWQO	No	No	-

Table A.7: Screening of Non-Radiological Lake Water COPCs for Ecological Health

Parameters	Unit	2015 Lake Water Results		Screening Criteria		Exceeds Screening Criteria?	Carried Forward as COPC for the EcoRA?	Notes
		Mean Background in 2015 (LWC-1)	Maximum Observed Lake Water in 2015	Selected Screening Level (e)	Source / Basis			
Petroleum Hydrocarbons								
PHC F1(C6-C10)-BTEX	mg/L	<0.025	<0.025	0.025	(4) Background	No	No	-
PHC F1 (C6-C10)	mg/L	<0.025	<0.025	0.025	(4) Background	No	No	-
PHC F2 (C10-C16)	mg/L	<0.1	<0.1	0.1	(4) Background	No	No	-
PHC F3 (C16-C34)	mg/L	<0.2	<0.2	0.2	(4) Background	No	No	-
PHC F4 (C34-C50)	mg/L	<0.2	<0.2	0.2	(4) Background	No	No	-
Other								
Hydrazine	mg/L	-	0.00025[d]	0.0026	(1) FEQG	No	No	-
Morpholine	mg/L	<0.004	0.006	0.004	(2) iPWQO	**Yes**	**Yes**	**Max > iPWQO**
Radionuclides								
Carbon-14	Bq/L	<0.1	<0.1	--	--	-	-	Assessed quantitatively for public interest purposes
Cesium-134	Bq/L	<0.1	<0.3	--	--	-	-	
Cesium-137	Bq/L	<0.1	<0.1	--	--	-	-	
Cobalt-60	Bq/L	<0.1	<0.1	--	--	-	-	
Tritium	Bq/L	<4.4	69.1	--	--	-	-	

Notes:

a - PWQO state that alkalinity should not be decreased by more than 25% of the natural concentration

b - 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.

c - There are no ecological protection values for silicon. Silicon is an abundant element in the earth's crust.

d - Maximum value from 2014 Supplementary EMP Study (Ecometrix, 2015)

e - To estimate parameter-dependent guidelines the following values were used: Hardness (100 mg/L), pH (8.0), Total Organic Carbon (0.5 mg/L)

Bold Text	= Maximum observed lake water concentration in 2014 / 2015 exceeds screening criteria
-	= No value
--	= No associated screening criteria

References:

PWQO = Ontario Provincial Water Quality Objectives, MOEE 1994, updated July 1998

iPWQO = Interim Ontario Provincial Water Quality Objectives, MOE 1994, update July 1998

CEQG = Canadian Environmental Quality Guidelines, current to September 2021

FEQG = Federal Environmental Quality Guidelines, current to September 2021

Suter and Tsao, (1996). Toxicological Benchmarks for Screening Potential Contaminants of Concern for Effects on Aquatic Biota: 1996 Revision.

Borgmann et al., (2005). Toxicity of Sixty-Three Metals and Metalloids to Hyalella Azteca at Two Levels of Water Hardness.

British Columbia, (2021). British Columbia Working Water Quality Guidelines: Aquatic Life, Wildlife & Agriculture Feb 2021

Table A.8a: Screening of Storm Water COPCs for Ecological Health - PN U1-4

		Catchment 2				Catchment 1				Maximum Concentration in Discharge	Final Concentration in CCW	Final Concentration in CCW	Screening Criteria		Mean Background in 2015 (LWC-1)	Exceeds Screening Criteria?	Carried Forward as COPC for the EcoRA?
Station ID		MH137				MH149							Selected Screening Level	Source / Basis			
Sample 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								
General	**Unit**																
Chloride	mg/L	25	25	27	24	650	110	790	150	790	1.5	1.5	120	(1) CEQG	-	No	No
Conductivity	mS/cm	0.31	0.301	0.323	0.29	2.32	0.521	2.99	0.714	2.99	-	-	--	See note (b)	0.3135	-	No
Hardness, Calcium Carbonate	mg/L	120	120	130	120	260	93	430	98	430	1	1	<25% background	(1) PWQO	127.5	No	No
pH	pH units	7.97	8.03	8.12	8.01	7.72	7.81	8.11	7.66	8.12	-	-	6.5 -- 8.5	(1) PWQO	7.9025	No	No
Phosphorous	mg/L	0.026	0.059	0.025	0.023	0.069	0.044	0.029	0.11	0.11	0.0002	0.0002	0.01	(1) PWQO	-	No	No
Total Suspended Solids	mg/L	< 10	46	< 10	<10	57	17	< 10	70	70	0.1	0.1	--	See note (b)	<1-<10	-	No
Toxicity																	
% Mortality of Daphnia Magna in 100% Effluent Treatment	%	0	0	0	0	0	0	0	0	0	0	0	--	--	-	N/A	No
% Mortality of Rainbow Trout in 100% Effluent Treatment	%	0	0	0	0	0	0	0	0	0	0	0	--	--	-	N/A	No
Metals																	
Aluminum	µg/L	67	300	110	19	680	350	57	1400	1400	3	3	100	(1) CEQG	7.08	No	No
Antimony	µg/L	< 0.50	< 0.50	< 0.50	<0.50	1	< 0.50	0.59	0.56	1	0.002	0.002	20	(2) iPWQO	<0.5	No	No
Arsenic	µg/L	< 1.0	< 1.0	< 1.0	<1.0	< 1.0	< 1.0	< 1.0	<1.0	< 1	<0.002	<0.002	5	(1) CEQG	<1	No	No
Barium	µg/L	26	28	26	22	64	19	67	31	67	0.1	0.1	1000	(3) BC Working WGG	22.25	No	No
Beryllium	µg/L	< 0.50	< 0.50	< 0.50	<0.50	< 0.50	< 0.50	< 0.50	<0.50	< 0.5	<0.001	<0.001	1100	(1) PWQO	<0.5	No	No
Bismuth	µg/L	< 1.0	< 1.0	< 1.0	<1.0	< 1.0	< 1.0	< 1.0	1.2	1.2	0.002	0.002	25.43	(3) Borgmann et al	<1	No	No
Boron	µg/L	26	19	24	15	32	11	19	<10	32	0.06	0.06	1500	(1) CEQG	25.5	No	No
Cadmium	µg/L	< 0.10	< 0.10	< 0.10	<0.10	< 0.10	< 0.10	< 0.10	<0.10	< 0.1	<0.0002	<0.0002	0.16	(1) CEQG	0.0095	No	No
Calcium	µg/L	35000	38000	38000	32000	96000	29000	140000	48000	140000	274	274	11600	(3) Suter and Tsao	34000	No	No
Chromium	µg/L	< 5.0	< 5.0	< 5.0	<5.0	< 5.0	< 5.0	< 5.0	<5.0	< 5	<0.01	<0.01	8.9	(1) PWQO, CEQG	<5	No	No
Cobalt	µg/L	< 0.50	< 0.50	< 0.50	<0.50	0.65	< 0.50	< 0.50	1	1	0.002	0.002	1	(1) FEQG	<0.5	No	No
Copper	µg/L	3.7	5.7	3.7	1.9	7.3	6.5	3.7	8.6	8.6	0.02	0.02	2.36	(1) CEQG	<1	No	No
Iron	µg/L	110	570	200	<100	1200	450	130	1800	1800	4	4	300	(1) PWQO, CEQG	<100	No	No
Lead	µg/L	< 0.50	1.1	< 0.50	<0.50	2.7	1.5	< 0.50	5.2	5.2	0.01	0.01	2.8	(1) FEQG	<0.5	No	No
Lithium	µg/L	< 5.0	< 5.0	< 5.0	<5.0	< 5.0	< 5.0	< 5.0	<5.0	< 5	<0.01	<0.01	14	(3) Suter and Tsao	<5	No	No
Magnesium	µg/L	8900	8400	8700	8100	13000	3500	20000	5200	20000	39	39	8200	(3) Suter and Tsao	8775	No	No
Manganese	µg/L	13	37	9.3	2.8	110	59	16	120	120	0.2	0.2	370	(1) CEQG	<2	No	No
Mercury (filtered)	µg/L	< 0.01	< 0.01	< 0.01	<0.01	< 0.01	< 0.01	< 0.01	<0.01	< 0.01	<0.00002	<0.00002	0.026	(1) CEQG	0.01	No	No
Molybdenum	µg/L	1.2	0.96	1.2	1.1	1.3	< 0.50	1.2	0.64	1.3	0.003	0.003	73	(1) CEQG	1.3	No	No
Nickel	µg/L	< 1.0	1.3	< 1.0	<1.0	2.5	< 1.0	< 1.0	2.6	2.6	0.005	0.005	25	(1) PWQO	1.025	No	No
Potassium	µg/L	1700	1600	1700	1600	2200	1100	2400	1900	2400	5	5	5300	(3) Suter and Tsao	1625	No	No
Selenium	µg/L	< 2.0	< 2.0	< 2.0	<2.0	< 2.0	< 2.0	< 2.0	<2.0	< 2	<0.004	<0.004	1	(1) CEQG	0.13875	No	No
Silicon	µg/L	240	810	530	370	2900	1300	2800	3400	3400	7	7	260	(4) Background	260	No	No
Silver	µg/L	< 0.10	< 0.10	< 0.10	<0.10	< 0.10	< 0.10	< 0.10	<0.10	< 0.1	<0.0002	<0.0002	0.1	(1) PWQO	<0.1	No	No
Sodium	µg/L	15000	14000	16000	14000	380000	63000	430000	99000	430000	842	842	68000	(3) Suter and Tsao	14500	No	No
Strontium	µg/L	180	170	190	170	680	190	890	300	890	2	2	2500	(1) FEQG	180	No	No
Tellurium	µg/L	< 1.0	< 1.0	< 1.0	<1.0	< 1.0	< 1.0	< 1.0	<1.0	< 1	<0.002	<0.002	15.19	(3) Borgmann et al	<1	No	No
Thallium	µg/L	< 0.050	< 0.050	< 0.050	<0.050	< 0.050	< 0.050	< 0.050	0.053	0.053	0.0001	0.0001	0.8	(1) CEQG	<0.05	No	No
Tin	µg/L	< 1.0	< 1.0	< 1.0	<1.0	< 1.0	< 1.0	< 1.0	<1.0	< 1	<0.002	<0.002	73	(3) Suter and Tsao	<1	No	No
Titanium	µg/L	< 5.0	16	7.1	<5.0	30	11	< 5.0	49	49	0.1	0.1	100	(3) Borgmann et al	<5	No	No
Tungsten	µg/L	< 1.0	< 1.0	< 1.0	<1.0	< 1.0	< 1.0	< 1.0	<1.0	< 1	<0.002	<0.002	30	(2) iPWQO	<1	No	No
Uranium	µg/L	0.89	0.46	0.62	0.45	0.3	0.33	0.58	0.37	0.89	0.002	0.002	15	(1) CEQG	0.3675	No	No
Vanadium	µg/L	0.53	1.1	< 0.50	<0.50	2.9	1.2	< 0.50	3.6	3.6	0.007	0.007	120	(1) FEQG	<0.5	No	No
Zinc	µg/L	< 5.0	20	12	<5.0	83	43	39	84	84	0.2	0.2	30	(1) PWQO	<5	No	No
Zirconium	µg/L	< 1.0	< 1.0	< 1.0	<1.0	< 1.0	< 1.0	< 1.0	1.1	1.1	0.002	0.002	4	(2) iPWQO	<1	No	No

Table A.8a: Screening of Storm Water COPCs for Ecological Health - PN U1-4

		Catchment 2				Catchment 1				Maximum Concentration in Discharge	Final Concentration in CCW	Final Concentration in CCW	Screening Criteria		Mean Background in 2015 (LWC-1)	Exceeds Screening Criteria?	Carried Forward as COPC for the EcoRA?
	Station ID	MH137				MH149							Selected Screening Level	Source / Basis			
	Sample 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								
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	<0.0004	<0.0004	100	(2) iPWQO	-	No	No
Toluene	µg/L	0.22	< 0.20	< 0.20	<0.20	< 0.20	< 0.20	< 0.20	<0.20	0.22	0.0004	0.0004	0.8	(2) iPWQO	-	No	No
Ethylbenzene	µg/L	< 0.20	< 0.20	< 0.20	<0.20	< 0.20	< 0.20	< 0.20	<0.20	< 0.2	<0.0004	<0.0004	8	(2) iPWQO	-	No	No
o-Xylene	µg/L	< 0.20	< 0.20	< 0.20	<0.20	< 0.20	< 0.20	< 0.20	<0.20	< 0.2	<0.0004	<0.0004	40	(2) iPWQO	-	No	No
m,p-Xylenes	µg/L	< 0.40	< 0.40	< 0.40	<0.40	< 0.40	< 0.40	< 0.40	<0.40	< 0.4	<0.0008	<0.0008	2	(2) iPWQO	-	No	No
Xylenes, Total	µg/L	< 0.40	< 0.40	< 0.40	<0.40	< 0.40	< 0.40	< 0.40	<0.40	< 0.4	<0.0008	<0.0008	2	(2) iPWQO	-	No	No
Petroleum Hydrocarbons - F1 (C6-C10)-BTEX	µg/L	< 25	< 25	< 25	<25	< 25	< 25	< 25	<25	< 25	<0.05	<0.05	<25	(4) Background	<25	No	No
Petroleum Hydrocarbons - F1 (C6-C10)	µg/L	< 25	< 25	< 25	<25	< 25	< 25	< 25	<25	< 25	<0.05	<0.05	<25	(4) Background	<25	No	No
Petroleum Hydrocarbons - F2 (C10-C16)	µg/L	< 100	< 100	< 100	<100	< 100	< 100	< 100	<100	< 100	<0.2	<0.2	<100	(4) Background	<100	No	No
Petroleum Hydrocarbons - F3 (C16-C34)	µg/L	< 200	< 200	< 200	<200	< 200	< 200	< 200	<200	< 200	<0.4	<0.4	<200	(4) Background	<200	No	No
Petroleum Hydrocarbons - F4 (C34-C50)	µg/L	< 200	< 200	< 200	<200	< 200	< 200	< 200	<200	< 200	<0.4	<0.4	<200	(4) Background	<200	No	No
Radiological																	
Carbon-14	Bq/L	< 20	< 20	< 20	<20	< 20	< 20	< 20	<20	< 20	<0.04	<0.04	<0.1	(4) Background	<0.1	No	No
Cesium-134	Bq/L	< 1	< 1	< 1	<1	< 1	< 1	< 1	<1	< 1	<0.002	<0.002	<0.1	(4) Background	<0.1	No	No
Cesium-137	Bq/L	< 1	< 1	< 1	<1	< 1	< 1	< 1	<1	< 1	<0.002	<0.002	50	(1) PWQO	<0.1	No	No
Cobalt-60	Bq/L	-	< 1	< 1	<1	-	< 1	< 1	<1	< 1	<0.002	<0.002	<0.1	(4) Background	<0.1	No	No
Iodine-131	Bq/L	< 1	< 1	< 1	<1	< 1	< 1	< 1	<1	< 1	<0.002	<0.002	10	(1) PWQO	-	No	No
Manganese-54	Bq/L	< 1	-	-	-	< 1	-	-	-	< 1	<0.002	<0.002	--	--	-	No	No
Tritium (HTO)	Bq/L	21	588	145	163	327	141	882	235	882	2	2	7000	(1) PWQO	<4.4	No	No
Zinc-65	Bq/L	< 1	-	-	-	< 1	-	-	-	< 1	<0.002	<0.002	--	--	-	No	No

Notes:

a - PWQO state that alkalinity should not be decreased by more than 25% of the natural concentration

b - 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.

c - There are no ecological protection values for silicon. Silicon is an abundant element in the earth's crust.

d - Maximum value from 2014 Supplementary EMP Study (Ecometrix, 2015)

e - To estimate parameter-dependent guidelines the following values were used: Hardness (100 mg/L), pH (8.0), Total Organic Carbon (0.5 mg/L)

Bold Text	= Exceeds Surface Water Quality Benchmark
-	= No value
--	= No associated screening criteria

References:

PWQO = Ontario Provincial Water Quality Objectives, MOEE 1994, updated July 1998

iPWQO = Interim Ontario Provincial Water Quality Objectives, MOE 1994, update July 1998

CEQG = Canadian Environmental Quality Guidelines, current to September 2021

FEQG = Federal Environmental Quality Guidelines, current to September 2021

Suter and Tsao, (1996). Toxicological Benchmarks for Screening Potential Contaminants of Concern for Effects on Aquatic Biota: 1996 Revision.

Borgmann et al., (2005). Toxicity of Sixty-Three Metals and Metalloids to Hyalella Azteca at Two Levels of Water Hardness.

British Columbia. (2021). British Columbia Working Water Quality Guidelines: Aquatic Life, Wildlife & Agriculture Feb 2021

Table A.8b: Screening of Storm Water COPCs for Ecological Health - PN U5-8

Station ID		Catchment 8 M3-3					Catchment 6 MH15				Maximum Concentration in Discharge	Final Concentration in CCW	Screening Criteria		Mean Background in 2015 (LWC-1)	Exceeds Screening Criteria?	Carried Forward as COPC for the EcoRA?
Sample Date		20-Aug-15	19-Nov-15	28-Oct-15	11-Jun-16		20-Aug-15	28-Oct-15	19-Nov-15	11-Jun-16			Selected Screening Level	Source / Basis			
General	**Unit**					Dup of M3-3											
Chloride	mg/L	650	340	120	200	200	47	40	38	14	650	2	120	(1) CEQG	-	No	No
Conductivity	mS/cm	2.36	1.4	0.541	0.922	0.944	0.276	0.35	0.305	0.12	2.36	0.006	--	See note (b)	0.3135	-	No
Hardness, Calcium Carbonate	mg/L	160	120	69	90	90	49	99	86	30	160	0.4	<25% background	(1) PWQO	127.5	No	No
pH	pH units	7.91	7.83	7.77	7.91	7.87	7.47	7.85	7.84	7.8	7.91	-	6.5 - 8.5	(1) PWQO	7.9025	No	No
Phosphorous	mg/L	0.029	0.025	0.037	0.05	0.052	0.54	0.16	0.27	0.13	0.54	0.001	0.01	(1) PWQO	-	No	No
Total Suspended Solids	mg/L	< 10	< 10	13	47	34	19	16	66	15	66	0.18	--	See note (b)	<1-<10	-	No
Toxicity																	
% Mortality of Daphnia Magna in 100% Effluent Treatment	%	0	0	0	0	-	0	0	0	0	-	-	--	--	-	N/A	No
% Mortality of Rainbow Trout in 100% Effluent Treatment	%	0	0	0	0	-	0	0	0	0	-	-	--	--	-	N/A	No
Metals																	
Aluminum	µg/L	110	79	460	390	370	270	210	1300	440	1300	3.5	100	(1) CEQG	7.075	No	No
Antimony	µg/L	0.56	0.52	0.51	0.95	0.91	0.64	0.84	< 0.50	0.93	0.95	0.003	20	(2) iPWQO	<0.5	No	No
Arsenic	µg/L	< 1.0	< 1.0	< 1.0	1.4	1.5	< 1.0	< 1.0	< 1.0	<1.0	1.5	0.004	5	(1) CEQG	<1	No	No
Barium	µg/L	37	21	12	20	20	14	24	25	8.5	37	0.1	1000	(3) BC Working WGG	22.25	No	No
Beryllium	µg/L	< 0.50	< 0.50	< 0.50	<0.50	<0.50	< 0.50	< 0.50	< 0.50	<0.50	< 0.5	<0.001	1100	(1) PWQO	<0.5	No	No
Bismuth	µg/L	< 1.0	< 1.0	< 1.0	<1.0	<1.0	< 1.0	< 1.0	< 1.0	<1.0	< 1	<0.003	25.43	(3) Borgmann et al	<1	No	No
Boron	µg/L	45	14	< 10	13	12	16	17	12	<10	45	0.1	1500	(1) CEQG	25.5	No	No
Cadmium	µg/L	< 0.10	< 0.10	< 0.10	0.2	0.23	< 0.10	< 0.10	< 0.10	<0.10	0.23	0.0006	0.16	(1) CEQG	0.0095	No	No
Calcium	µg/L	52000	38000	21000	39000	38000	19000	27000	36000	14000	52000	139	11600	(3) Suter and Tsao	34000	No	No
Chromium	µg/L	< 5.0	< 5.0	< 5.0	5.1	<5.0	< 5.0	< 5.0	< 5.0	<5.0	5.1	0.01	8.9	(1) PWQO, CEQG	<5	No	No
Cobalt	µg/L	< 0.50	< 0.50	< 0.50	0.97	0.95	< 0.50	< 0.50	0.88	<0.50	0.97	0.003	1	(1) FEQG	<0.5	No	No
Copper	µg/L	6.2	3.6	5	12	11	11	7.1	7.4	7.5	12	0.03	2.36	(1) CEQG	<1	No	No
Iron	µg/L	370	130	550	710	660	340	280	1600	510	1600	4	300	(1) PWQO, CEQG	<100	No	No
Lead	µg/L	0.66	0.54	1.8	3.1	2.9	1.3	0.89	2.2	1.6	3.1	0.01	2.8	(1) FEQG	<0.5	No	No
Lithium	µg/L	< 5.0	< 5.0	< 5.0	<5.0	<5.0	< 5.0	< 5.0	< 5.0	<5.0	< 5	<0.01	14	(3) Suter and Tsao	<5	No	No
Magnesium	µg/L	6800	5300	2000	3300	3200	2200	4800	4700	1000	6800	18	8200	(3) Suter and Tsao	8775	No	No
Manganese	µg/L	96	20	33	60	60	27	20	63	24	96	0.3	370	(1) CEQG	<2	No	No
Mercury (filtered)	µg/L	< 0.01	< 0.01	< 0.01	<0.01	0.01	< 0.01	< 0.01	0.02	<0.01	0.02	0.00005	0.026	(1) CEQG	0.01	No	No
Molybdenum	µg/L	1.1	0.66	< 0.50	3.3	3.4	0.54	1.3	0.55	0.71	3.4	0.01	73	(1) CEQG	1.3	No	No
Nickel	µg/L	1.6	1	1.3	4.1	3.6	< 1.0	< 1.0	2.4	<1.0	4.1	0.01	25	(1) PWQO	1.025	No	No
Potassium	µg/L	1300	960	900	10000	9700	1200	1500	1200	1200	10000	27	5300	(3) Suter and Tsao	1625	No	No
Selenium	µg/L	< 2.0	< 2.0	< 2.0	<2.0	<2.0	< 2.0	< 2.0	< 2.0	<2.0	< 2	<0.005	1	(1) CEQG	0.13875	No	No
Silicon	µg/L	1100	760	1100	2300	2200	1100	1500	3100	1100	3100	8	260	(4) Background	260	No	No
Silver	µg/L	< 0.10	< 0.10	< 0.10	<0.10	<0.10	< 0.10	< 0.10	< 0.10	<0.10	< 0.1	<0.0003	0.1	(1) PWQO	<0.1	No	No
Sodium	µg/L	420000	220000	77000	140000	130000	35000	31000	27000	9900	420000	1122	68000	(3) Suter and Tsao	14500	No	No
Strontium	µg/L	390	230	120	290	280	300	770	670	86	770	2	2500	(1) FEQG	180	No	No
Tellurium	µg/L	< 1.0	< 1.0	< 1.0	<1.0	<1.0	< 1.0	< 1.0	< 1.0	<1.0	< 1	<0.003	15.19	(3) Borgmann et al	<1	No	No
Thallium	µg/L	< 0.050	< 0.050	< 0.050	<0.050	<0.050	< 0.050	< 0.050	< 0.050	<0.050	< 0.05	<0.0001	0.8	(1) CEQG	<0.05	No	No
Tin	µg/L	< 1.0	< 1.0	< 1.0	6.1	6.1	< 1.0	< 1.0	< 1.0	<1.0	6.1	0.02	73	(3) Suter and Tsao	<1	No	No
Titanium	µg/L	6.3	5.4	16	16	16	18	7.9	44	23	44	0.1	100	(3) Borgmann et al	<5	No	No
Tungsten	µg/L	< 1.0	< 1.0	< 1.0	<1.0	<1.0	< 1.0	< 1.0	< 1.0	<1.0	< 1	<0.003	30	(2) iPWQO	<1	No	No
Uranium	µg/L	0.16	0.24	< 0.10	0.21	0.22	< 0.10	0.32	0.17	0.13	0.32	0.001	15	(1) CEQG	0.3675	No	No
Vanadium	µg/L	2.4	0.91	2.1	8.3	8.2	3.8	1.3	3.6	2.2	8.3	0.02	120	(1) FEQG	<0.5	No	No
Zinc	µg/L	39	41	40	73	71	160	80	130	91	160	0.4	30	(1) PWQO	<5	No	No
Zirconium	µg/L	< 1.0	< 1.0	< 1.0	<1.0	<1.0	< 1.0	< 1.0	< 1.0	<1.0	< 1	<0.003	4	(2) iPWQO	<1	No	No

Table A.8b: Screening of Storm Water COPCs for Ecological Health - PN U5-8

		Catchment 8 M3-3					Catchment 6 MH15				Maximum Concentration in Discharge	Final Concentration in CCW	Screening Criteria		Mean Background in 2015 (LWC-1)	Exceeds Screening Criteria?	Carried Forward as COPC for the EcoRA?
	Station ID												Selected Screening Level	Source / Basis			
	Sample Date	20-Aug-15	19-Nov-15	28-Oct-15	11-Jun-16		20-Aug-15	28-Oct-15	19-Nov-15	11-Jun-16							
Petroleum Hydrocarbons (and BTEX)																	
Benzene	µg/L	< 0.20	< 0.20	< 0.20	<0.20	<0.20	< 0.20	< 0.20	< 0.20	<0.20	< 0.2	<0.0005	100	(2) iPWQO	-	No	No
Toluene	µg/L	0.31	< 0.20	< 0.20	<0.20	<0.20	< 0.20	< 0.20	< 0.20	<0.20	0.31	0.001	0.8	(2) iPWQO	-	No	No
Ethylbenzene	µg/L	< 0.20	< 0.20	< 0.20	<0.20	<0.20	< 0.20	< 0.20	< 0.20	<0.20	< 0.2	<0.0005	8	(2) iPWQO	-	No	No
o-Xylene	µg/L	< 0.20	< 0.20	< 0.20	<0.20	<0.20	< 0.20	< 0.20	0.38	<0.20	0.38	0.001	40	(2) iPWQO	-	No	No
m,p-Xylenes	µg/L	< 0.40	< 0.40	< 0.40	<0.40	<0.40	< 0.40	< 0.40	0.46	<0.40	0.46	0.001	2	(2) iPWQO	-	No	No
Xylenes, Total	µg/L	< 0.40	< 0.40	< 0.40	<0.40	<0.40	< 0.40	< 0.40	0.84	<0.40	0.84	0.002	2	(2) iPWQO	-	No	No
Petroleum Hydrocarbons - F1 (C6-C10)-BTEX	µg/L	< 25	< 25	< 25	<25	<25	< 25	< 25	< 25	<25	< 25	<0.07	<25	(4) Background	<25	No	No
Petroleum Hydrocarbons - F1 (C6-C10)	µg/L	< 25	< 25	< 25	<25	<25	< 25	< 25	< 25	<25	< 25	<0.07	<25	(4) Background	<25	No	No
Petroleum Hydrocarbons - F2 (C10-C16)	µg/L	< 100	< 100	< 100	<100	<100	< 100	< 100	< 100	<100	< 100	<0.3	<100	(4) Background	<100	No	No
Petroleum Hydrocarbons - F3 (C16-C34)	µg/L	< 200	< 200	< 200	<200	<200	< 200	< 200	< 200	<200	< 200	<0.5	<200	(4) Background	<200	No	No
Petroleum Hydrocarbons - F4 (C34-C50)	µg/L	< 200	< 200	< 200	<200	<200	< 200	< 200	< 200	<200	< 200	<0.5	<200	(4) Background	<200	No	No
Radiological																	
Carbon-14	Bq/L	< 20	< 20	< 20	<20	<20	< 20	< 20	< 20	<20	< 20	<0.05	<0.1	(4) Background	<0.1	No	No
Cesium-134	Bq/L	< 1	< 1	< 1	<1	<1	< 1	< 1	< 1	<1	< 1	<0.003	<0.1	(4) Background	<0.1	No	No
Cesium-137	Bq/L	< 1	< 1	< 1	<1	<1	< 1	< 1	< 1	<1	< 1	<0.003	50	(1) PWQO	<0.1	No	No
Cobalt-60	Bq/L	-	< 1	< 1	<1	<1	-	< 1	< 1	<1	< 1	<0.003	<0.1	(4) Background	<0.1	No	No
Iodine-131	Bq/L	< 1	< 1	< 1	<1	<1	< 1	< 1	< 1	<1	< 1	<0.003	10	(1) PWQO	-	No	No
Manganese-54	Bq/L	< 1	-	-	-	-	< 1	-	-	-	< 1	<0.003	--	--	-	No	No
Tritium (HTO)	Bq/L	974	145	50	78	79	182	1400	1110	1370	1400	4	7000	(1) PWQO	<4.4	No	No
Zinc-65	Bq/L	< 1	-	-	-	-	< 1	-	-	-	< 1	<0.003	--	--	-	No	No

Notes:

a - PWQO state that alkalinity should not be decreased by more than 25% of the natural concentration

b - 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.

c - There are no ecological protection values for silicon. Silicon is an abundant element in the earth's crust.

d - Maximum value from 2014 Supplementary EMP Study (Ecometrix, 2015)

e - To estimate parameter-dependent guidelines the following values were used: Hardness (100 mg/L), pH (8.0), Total Organic Carbon (0.5 mg/L)

Bold Text	= Exceeds Surface Water Quality Benchmark
-	= No value
--	= No associated screening criteria

References:

PWQO = Ontario Provincial Water Quality Objectives, MOEE 1994, updated July 1998

iPWQO = Interim Ontario Provincial Water Quality Objectives, MOE 1994, update July 1998

CEQG = Canadian Environmental Quality Guidelines, current to September 2021

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Suter and Tsao, (1996). Toxicological Benchmarks for Screening Potential Contaminants of Concern for Effects on Aquatic Biota: 1996 Revision.

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British Columbia. (2021). British Columbia Working Water Quality Guidelines: Aquatic Life, Wildlife & Agriculture Feb 2021

Table A.8c: Screening of Storm Water COPCs for Ecological Health - Lake Water East

	Concentration									Loading										Screening							
Location	Units	Catchment 10				Catchment 13				Units	Catchment 10				Catchment 13				Max Loading	Units	Final Concentration in Lake	Screening Criteria		Mean Background in 2015 (LWC-1)	Exceeds Screening Criteria?	Carried Forward as COPC for the EcoRA?
Station ID		M2-1				M5-1					M2-1				M5-1											
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		20-Aug-15	28-Oct-15	19-Nov-15	11-Jun-16	20-Aug-15	28-Oct-15	19-Nov-15	11-Jun-16				Selected Screening Level	Source / Basis			
General																										
Chloride	mg/L	600	110	890	180	320	16	340	92	mg/s	1136	1550	561	8700	11872	1106	3093	25283	25283	mg/L	1	120	(1) CEQG	-	No	No
Conductivity	mS/cm	2.2	0.539	3.38	0.814	1.36	0.135	1.59	0.455		4.16	7.60	2.13	39.34	50.46	9.33	14.46	125.04	125	mS/cm	3.38	--	See note (b)	0.3135	-	No
Hardness, Calcium Carbonate	mg/L	150	81	330	76	130	41	190	63	mg/s	284	1142	208	3673	4823	2835	1728	17313	17313	mg/L	1	<25% background	(1) PWQO	127.5	No	No
pH	pH units	7.85	7.68	7.8	7.98	7.82	6.76	7.87	7.95		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	pH units	N/A	6.5 - 8.5	(1) PWQO	7.9025	No	No
Phosphorous	mg/L	0.096	0.065	0.038	0.11	0.092	0.061	0.032	0.12	mg/s	0.18	0.92	0.02	5.32	3.41	4.22	0.29	32.98	32.98	mg/L	0.001	0.01	(1) PWQO	-	No	No
Total Suspended Solids	mg/L	72	46	20	110	< 10	25	< 10	82	mg/s	136	648	13	5316	<371	1728	<91	22535	22535	mg/L	1	--	See note (b)	<1-<10	-	No
Metals																										
Aluminum	µg/L	1800	990	740	1500	170	970	53	1600	µg/s	3408	13952	466	72496	6307	67060	482	439702	439702	µg/L	15	100	(1) CEQG	7.075	No	No
Antimony	µg/L	0.84	1.4	0.64	0.61	0.51	0.62	< 0.50	0.88	µg/s	1.6	20	0	29.5	18.9	43	<5	242	242	µg/L	0.01	20	(2) iPWQO	<0.5	No	No
Arsenic	µg/L	< 1.0	< 1.0	< 1.0	<1.0	< 1.0	< 1.0	< 1.0	<1.0	µg/s	<2	<14	<1	<48	<37	<69	<9	<275	< 275	µg/L	<0.01	5	(1) CEQG	<1	No	No
Barium	µg/L	50	20	73	35	29	9.3	32	41	µg/s	95	282	46	1692	1076	643	291	11267	11267	µg/L	0	1000	(3) BC Working WGG	22.25	No	No
Beryllium	µg/L	< 0.50	< 0.50	< 0.50	<0.50	< 0.50	< 0.50	< 0.50	<0.50	µg/s	<0.9	<7.0	<0.3	<24.2	<18.6	<34.6	<4.5	<137.4	< 137	µg/L	<0.00	1100	(1) PWQO	<0.5	No	No
Bismuth	µg/L	< 1.0	< 1.0	< 1.0	<1.0	< 1.0	< 1.0	< 1.0	<1.0	µg/s	<2	<14	<1	<48	<37	<69	<9	<275	< 275	µg/L	<0.01	25.43	(3) Borgmann et al	<1	No	No
Boron	µg/L	48	11	35	<10	41	< 10	43	13	µg/s	91	155	22	<483	1521	<691	391	3573	3573	µg/L	0.1	1500	(1) CEQG	25.5	No	No
Cadmium	µg/L	< 0.10	< 0.10	< 0.10	<0.10	< 0.10	< 0.10	< 0.10	<0.10	µg/s	<0.2	<1.4	<0.1	<4.8	<3.7	<6.9	<0.9	<27.5	< 27.5	µg/L	<0.001	0.16	(1) CEQG	0.0095	No	No
Calcium	µg/L	65000	34000	100000	66000	41000	16000	54000	47000	µg/s	123050	479153	63028	3189817	1521119	1106148	491228	12916253	12916253	µg/L	438	11600	(3) Suter and Tsao	34000	No	No
Chromium	µg/L	< 5.0	< 5.0	< 5.0	8.7	< 5.0	< 5.0	< 5.0	5.2	µg/s	<9	<70	<3	420	<186	<346	<45	1429	1429	µg/L	0.0	8.9	(1) PWQO, CEQG	<5	No	No
Cobalt	µg/L	1	< 0.50	0.57	1.2	< 0.50	< 0.50	< 0.50	1.1	µg/s	2	<7.0	0.36	58	<18.6	<34.6	<4.5	302	302	µg/L	0.010	1	(1) FEQG	<0.5	No	No
Copper	µg/L	18	4.3	3.9	8	7.6	3.2	2.4	6.2	µg/s	34	61	2	387	282	221	22	1704	1704	µg/L	0.1	2.36	(1) CEQG	<1	No	No
Iron	µg/L	1800	1200	760	3100	310	720	< 100	1900	µg/s	3408	16911	479	149825	11501	49777	<910	522146	522146	µg/L	18	300	(1) PWQO, CEQG	<100	No	No
Lead	µg/L	3.8	2.8	1.1	6.2	0.55	1.6	< 0.50	4	µg/s	7	39	1	300	20.4	111	<4.5	1099	1099	µg/L	0.0	2.8	(1) FEQG	<0.5	No	No
Lithium	µg/L	5.6	< 5.0	5.2	<5.0	< 5.0	< 5.0	< 5.0	5.1	µg/s	11	<70	3	<242	<186	<346	<45	1402	1402	µg/L	0.0	14	(3) Suter and Tsao	<5	No	No
Magnesium	µg/L	7200	3100	16000	4500	6100	1300	9400	3500	µg/s	13630	43688	10084	217488	226313	89874	85510	961849	961849	µg/L	33	8200	(3) Suter and Tsao	8775	No	No
Manganese	µg/L	170	56	220	200	66	30	27	81	µg/s	322	789	139	9666	2449	2074	246	22260	22260	µg/L	1	370	(1) CEQG	<2	No	No
Mercury (filtered)	µg/L	< 0.01	< 0.01	< 0.01	<0.01	< 0.01	< 0.01	< 0.01	<0.01	µg/s	<0.02	<0.14	<0.01	<0.48	<0.37	<0.69	<0.09	<2.75	< 2.75	µg/L	<0.0001	0.026	(1) CEQG	0.01	No	No
Molybdenum	µg/L	1.8	0.56	1.9	0.8	1.2	< 0.50	1.8	0.58	µg/s	3.4	7.9	1.2	38.7	44.5	<34.6	16.4	159.4	159	µg/L	0.01	73	(1) CEQG	1.3	No	No
Nickel	µg/L	3	1.8	1.5	4.2	1.4	1.6	< 1.0	3	µg/s	6	25	1	203	52	111	<9	824	824	µg/L	0.03	25	(1) PWQO	1.025	No	No
Potassium	µg/L	3200	1700	3400	2300	2500	1100	2200	2400	µg/s	6058	23958	2143	111160	92751	76048	20013	659553	659553	µg/L	22	5300	(3) Suter and Tsao	1625	No	No
Selenium	µg/L	< 2.0	< 2.0	< 2.0	<2.0	< 2.0	< 2.0	< 2.0	<2.0	µg/s	<4	<28	<1	<97	<74	<138	<18	<550	< 550	µg/L	<0.02	1	(1) CEQG	0.13875	No	No
Silicon	µg/L	5000	2300	3800	4400	1100	2000	930	7600	µg/s	9465	32413	2395	212654	40811	138268	8460	2088586	2088586	µg/L	71	260	(4) Background	260	No	No
Silver	µg/L	< 0.10	< 0.10	< 0.10	<0.10	< 0.10	< 0.10	< 0.10	<0.10	µg/s	<0.2	<1.4	<0.1	<4.8	<3.7	<6.9	<0.9	<27.5	< 27.5	µg/L	<0.001	0.1	(1) PWQO	<0.1	No	No
Sodium	µg/L	400000	71000	540000	130000	220000	11000	250000	59000	µg/s	757230	1000585	340351	6282972	8162100	760476	2274204	16214019	16214019	µg/L	550	68000	(3) Suter and Tsao	14500	No	No
Strontium	µg/L	400	160	680	230	660	110	1000	360	µg/s	757	2255	429	11116	24486	7605	9097	98933	98933	µg/L	3	2500	(1) FEQG	180	No	No
Tellurium	µg/L	< 1.0	< 1.0	< 1.0	<1.0	< 1.0	< 1.0	< 1.0	<1.0	µg/s	<2	<14	<1	<48	<37	<69	<9	<275	< 275	µg/L	<0.01	15.19	(3) Borgmann et al	<1	No	No
Thallium	µg/L	< 0.050	< 0.050	< 0.050	<0.050	< 0.050	< 0.050	< 0.050	<0.050	µg/s	<0.09	<0.70	<0.03	<2.42	<1.86	<3.46	<0.45	<13.74	< 13.74	µg/L	<0.000	0.8	(1) CEQG	<0.05	No	No
Tin	µg/L	< 1.0	< 1.0	< 1.0	<1.0	< 1.0	< 1.0	< 1.0	<1.0	µg/s	<2	<14	<1	<48	<37	<69	<9	<275	< 275	µg/L	<0.01	73	(3) Suter and Tsao	<1	No	No
Titanium	µg/L	66	38	13	53	6.2	26	< 5.0	43	µg/s	125	536	8	2562	230	1797	<45	11817	11817	µg/L	0	100	(3) Borgmann et al	<5	No	No
Tungsten	µg/L	< 1.0	< 1.0	< 1.0	<1.0	< 1.0	< 1.0	< 1.0	<1.0	µg/s	<2	<14	<1	<48	<37	<69	<9	<275	< 275	µg/L	<0.01	30	(2) iPWQO	<1	No	No
Uranium	µg/L	0.3	0.19	0.78	0.27	0.17	< 0.10	0.64	0.6	µg/s	0.6	2.7	0.5	13.0	6.3	6.9	<0.9	164.9	165	µg/L	0.01	15	(1) CEQG	0.3675	No	No
Vanadium	µg/L	5.1	2.6	1.7	5	1	1.6	< 0.50	4.8	µg/s	10	37	1	242	37	111	<4.5	1319	1319	µg/L	0.0	120	(1) FEQG	<0.5	No	No
Zinc	µg/L	100	91	99	190	69	38	61	72	µg/s	189	1282	62	9183	2560	2627	555	19787	19787	µg/L	1	30	(1) PWQO	<5	No	No
Zirconium	µg/L	1.2	< 1.0	< 1.0	1.1	< 1.0	< 1.0	< 1.0	2.7	µg/s	2	<14	<1	53	<37	<69	<9	742	742	µg/L	0.03	4	(2) iPWQO	<1	No	No

Table A.8c: Screening of Storm Water COPCs for Ecological Health - Lake Water East

		Concentration								Loading										Screening					
Location	Units	Catchment 10				Catchment 13				Units	Catchment 10				Catchment 13				Max Loading	Units	Final Concentration in Lake	Screening Criteria		Mean Background in 2015 (LWC-1)	Exceeds Screening Criteria?	Carried Forward as COPC for the EcoRA?
Station ID		M2-1				M5-1					M2-1				M5-1							Selected Screening Level	Source / Basis			
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		20-Aug-15	28-Oct-15	19-Nov-15	11-Jun-16	20-Aug-15	28-Oct-15	19-Nov-15	11-Jun-16								
Petroleum Hydrocarbons (and BTEX)																										
Benzene	µg/L	< 0.20	< 0.20	< 0.20	<0.20	< 0.20	< 0.20	< 0.20	<0.20	µg/s	<0.4	<2.8	<0.1	<9.7	<7.4	<13.8	<1.8	<55.0	< 55	µg/L	<0.002	100	(2) iPWQO	-	No	No
Toluene	µg/L	0.44	< 0.20	< 0.20	<0.20	0.44	< 0.20	< 0.20	<0.20	µg/s	0.8	<2.8	<0.1	<9.7	16.3	<13.8	<1.8	<55.0	< 55	µg/L	<0.002	0.8	(2) iPWQO	-	No	No
Ethylbenzene	µg/L	< 0.20	< 0.20	< 0.20	<0.20	< 0.20	< 0.20	< 0.20	<0.20	µg/s	<0.4	<2.8	<0.1	<9.7	<7.4	<13.8	<1.8	<55.0	< 55	µg/L	<0.002	8	(2) iPWQO	-	No	No
o-Xylene	µg/L	< 0.20	< 0.20	< 0.20	<0.20	< 0.20	< 0.20	< 0.20	<0.20	µg/s	<0.4	<2.8	<0.1	<9.7	<7.4	<13.8	<1.8	<55.0	< 55	µg/L	<0.002	40	(2) iPWQO	-	No	No
m,p-Xylenes	µg/L	< 0.40	< 0.40	< 0.40	<0.40	< 0.40	< 0.40	< 0.40	<0.40	µg/s	<0.8	<5.6	<0.3	<19.3	<14.8	<27.7	<3.6	<109.9	< 109.9	µg/L	<0.00	2	(2) iPWQO	-	No	No
Xylenes, Total	µg/L	< 0.40	< 0.40	< 0.40	<0.40	< 0.40	< 0.40	< 0.40	<0.40	µg/s	<0.8	<5.6	<0.3	<19.3	<14.8	<27.7	<3.6	<109.9	< 109.9	µg/L	<0.00	2	(2) iPWQO	-	No	No
Petroleum Hydrocarbons - F1 (C6-C10)-BTEX	µg/L	< 25	< 25	< 25	<25	< 25	< 25	< 25	<25	µg/s	<47	<352	<16	<1208	<928	<1728	<227	<6870	< 6870	µg/L	<0.2	<25	(4) Background	<25	No	No
Petroleum Hydrocarbons - F1 (C6-C10)	µg/L	< 25	< 25	< 25	<25	< 25	< 25	< 25	<25	µg/s	<47	<352	<16	<1208	<928	<1728	<227	<6870	< 6870	µg/L	<0.2	<25	(4) Background	<25	No	No
Petroleum Hydrocarbons - F2 (C10-C16)	µg/L	< 100	< 100	< 100	<100	< 100	< 100	< 100	<100	µg/s	<189	<1409	<63	<4833	<3710	<6913	<910	<27481	< 27481	µg/L	<1	<100	(4) Background	<100	No	No
Petroleum Hydrocarbons - F3 (C16-C34)	µg/L	< 200	< 200	< 200	<200	< 200	< 200	< 200	<200	µg/s	<379	<2819	<126	<9666	<7420	<13827	<1819	<54963	< 54963	µg/L	<2	<200	(4) Background	<200	No	No
Petroleum Hydrocarbons - F4 (C34-C50)	µg/L	< 200	< 200	< 200	<200	< 200	< 200	< 200	<200	µg/s	<379	<2819	<126	<9666	<7420	<13827	<1819	<54963	< 54963	µg/L	<2	<200	(4) Background	<200	No	No
Radiological																										
Carbon-14	Bq/L	< 20	< 20	< 20	<20	< 20	< 20	< 20	<20	Bq/s	<38	<282	<13	<967	<742	<1383	<182	<5496	< 5496	Bq/L	<0.2	<0.1	(4) Background	<0.1	No	No
Cesium-134	Bq/L	< 1	< 1	< 1	<1	< 1	< 1	< 1	<1	Bq/s	<2	<14	<1	<48	<37	<69	<9	<275	< 275	Bq/L	<0.01	<0.1	(4) Background	<0.1	No	No
Cesium-137	Bq/L	< 1	< 1	< 1	<1	< 1	< 1	< 1	<1	Bq/s	<2	<14	<1	<48	<37	<69	<9	<275	< 275	Bq/L	<0.01	50	(1) PWQO	<0.1	No	No
Cobalt-60	Bq/L	-	< 1	< 1	<1	-	< 1	< 1	<1	Bq/s	-	<14	<1	<48	-	<69	<9	<275	< 275	Bq/L	<0.01	<0.1	(4) Background	<0.1	No	No
Iodine-131	Bq/L	< 1	< 1	< 1	<1	< 1	< 1	< 1	<1	Bq/s	<2	<14	<1	<48	<37	<69	<9	<275	< 275	Bq/L	<0.01	10	(1) PWQO	-	No	No
Manganese-54	Bq/L	< 1	-	-	-	< 1	-	-	-	Bq/s	<2	-	-	-	<37	-	-	-	< 37	Bq/L	<0.0013	--	--	-	No	No
Tritium (Hydrogen-3)	Bq/L	227	41	222	53	158	< 15	111	<15	Bq/s	430	578	140	2562	5862	<1037	1010	<4122	5862	Bq/L	0.2	7000	(1) PWQO	<4.4	No	No
Zinc-65	Bq/L	< 1	-	-	-	< 1	-	-	-	Bq/s	<2	-	-	-	<37	-	-	-	< 37	Bq/L	<0.0013	--	--	-	No	No

Notes:

a - PWQO state that alkalinity should not be decreased by more than 25% of the natural concentration

b - 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.

c - There are no ecological protection values for silicon. Silicon is an abundant element in the earth's crust.

d - Maximum value from 2014 Supplementary EMP Study (Ecometrix, 2015)

e - To estimate parameter-dependent guidelines the following values were used: Hardness (100 mg/L), pH (8.0), Total Organic Carbon (0.5 mg/L)

Bold Text	= Exceeds Surface Water Quality Benchmark
-	= No value
--	= No associated screening criteria

References:

PWQO = Ontario Provincial Water Quality Objectives, MOEE 1994, updated July 1998

iPWQO = Interim Ontario Provincial Water Quality Objectives, MOE 1994, update July 1998

CEQG = Canadian Environmental Quality Guidelines, current to September 2021

FEQG = Federal Environmental Quality Guidelines, current to September 2021

Suter and Tsao, (1996). Toxicological Benchmarks for Screening Potential Contaminants of Concern for Effects on Aquatic Biota: 1996 Revision.

Borgmann et al., (2005). Toxicity of Sixty-Three Metals and Metalloids to Hyalella Azteca at Two Levels of Water Hardness.

British Columbia, (2021). British Columbia Working Water Quality Guidelines: Aquatic Life, Wildlife & Agriculture Feb 2021

Table A.8d: Screening of Stormwater COPCs for Ecological Health - Lake Water West

Location		Concentration							Loading								Screening						
		Catchment 3							Catchment 3										Screening Criteria				
Station ID	Units	MH211						Unit	MH211						Max Loading	Units	Final Concentration in Lake	Selected Screening Level	Source / Basis	Mean Background in 2015 (LWC-1)	Exceeds Screening Criteria?	Carried Forward as COPC for the EcoRA?
Date		20-Aug-15	28-Oct-15	19-Nov-15	20-Aug-15	11-Jun-16	2016-06-11 (dup)		20-Aug-15	28-Oct-15	19-Nov-15	20-Aug-15	11-Jun-16	2016-06-11 (Dup)								
General																						
Chloride	mg/L	22	2.1	36	22	2.6	2.4	mg/s	380	74	361	377	333	307	380	mg/L	0.02	120	(1) CEQG	-	No	No
Conductivity	mS/cm	0.225	0.073	0.314	0.225	0.063	0.064	mS/cm	N/A	N/A	N/A	N/A	N/A	N/A	< -	mS/cm	N/A	--	See note (b)	0.3135	-	No
Hardness, Calcium Carbonate	mg/L	62	32	89	63	23	23	mg/s	1071	1120	892	1080	2946	2946	2946	mg/L	0.1	<25% background	(1) PWQO	127.5	No	No
pH	pH units	7.6	7.66	7.92	7.55	7.49	7.56	pH units	N/A	N/A	N/A	N/A	N/A	N/A	< -	pH units	7.92	6.5 - 8.5	(1) PWQO	7.9025	No	No
Phosphorous	mg/L	0.16	0.06	0.083	0.16	0.11	0.11	mg/s	2.76	2.10	0.83	2.7	14	14	14	mg/L	0.0006	0.01	(1) PWQO	-	No	No
Total Suspended Solids	mg/L	40	11	< 10	34	<10	<10	mg/s	691	385	<100	583	<1281	<1281	< 1281	mg/L	<0.05	--	See note (b)	<1-<10	-	No
Metals																						
Aluminum	µg/L	550	160	130	570	120	100	µg/s	9499	5602	1304	9773	15371	12809	15371	µg/L	1	100	(1) CEQG	7.075	No	No
Antimony	µg/L	3.7	0.9	1.5	3.6	0.76	0.94	µg/s	64	32	15	62	97	120	120	µg/L	0.01	20	(2) iPWQO	<0.5	No	No
Arsenic	µg/L	< 1.0	< 1.0	< 1.0	< 1.0	<1.0	<1.0	µg/s	<17	<35	<10	<17	<128	<128	< 128	µg/L	<0.005	5	(1) CEQG	<1	No	No
Barium	µg/L	24	8.4	26	23	4.8	4.2	µg/s	414	294	261	394	615	538	615	µg/L	0.03	1000	(3) BC Working WGG	22.25	No	No
Beryllium	µg/L	< 0.50	< 0.50	< 0.50	< 0.50	<0.50	<0.50	µg/s	<8.6	<17.5	<5.0	<8.6	<64.0	<64.0	< 64	µg/L	<0.003	1100	(1) PWQO	<0.5	No	No
Bismuth	µg/L	< 1.0	< 1.0	< 1.0	< 1.0	<1.0	<1.0	µg/s	<17	<35	<10	<17	<128	<128	< 128	µg/L	<0.005	25.43	(3) Borgmann et al	<1	No	No
Boron	µg/L	29	< 10	14	28	<10	<10	µg/s	501	<350	140	480	<1281	<1281	< 1281	µg/L	<0.05	1500	(1) CEQG	25.5	No	No
Cadmium	µg/L	0.69	0.23	0.15	0.87	0.21	0.2	µg/s	12	8.1	1.5	15	27	26	27	µg/L	0.001	0.16	(1) CEQG	0.0095	No	No
Calcium	µg/L	27000	11000	32000	27000	8500	8600	µg/s	466310	385165	320868	462953	1088796	1101605	1101605	µg/L	47	11600	(3) Suter and Tsao	34000	No	No
Chromium	µg/L	< 5.0	< 5.0	< 5.0	< 5.0	<5.0	<5.0	µg/s	<86	<175	<50	<86	<640	<640	< 640	µg/L	<0.03	8.9	(1) PWQO, CEQG	<5	No	No
Cobalt	µg/L	0.73	< 0.50	< 0.50	0.72	<0.50	<0.50	µg/s	12.6	<18	<5	12	<64	<64	< 64	µg/L	<0.003	1	(1) FEQG	<0.5	No	No
Copper	µg/L	43	12	11	42	7.6	6.9	µg/s	743	420	110	720	974	884	974	µg/L	0.04	2.36	(1) CEQG	<1	No	No
Iron	µg/L	790	280	220	800	160	120	µg/s	13644	9804	2206	13717	20495	15371	20495	µg/L	1	300	(1) PWQO, CEQG	<100	No	No
Lead	µg/L	4.9	2.2	1.1	5.1	1.3	1.3	µg/s	85	77	11	87	167	167	167	µg/L	0.01	2.8	(1) FEQG	<0.5	No	No
Lithium	µg/L	< 5.0	< 5.0	< 5.0	< 5.0	<5.0	<5.0	µg/s	<86	<175	<50	<86	<640	<640	< 640	µg/L	<0.03	14	(3) Suter and Tsao	<5	No	No
Magnesium	µg/L	2200	690	2100	2300	520	480	µg/s	37996	24160	21057	39437	66609	61485	66609	µg/L	3	8200	(3) Suter and Tsao	8775	No	No
Manganese	µg/L	42	15	20	41	11	11	µg/s	725	525	201	703	1409	1409	1409	µg/L	0.06	370	(1) CEQG	<2	No	No
Mercury (filtered)	µg/L	< 0.01	< 0.01	0.01	< 0.01	<0.01	<0.01	µg/s	<0.17	<0.35	<0.10	<0.17	<1	<1	< 1.00	µg/L	<0.00004	0.026	(1) CEQG	0.01	No	No
Molybdenum	µg/L	0.99	< 0.50	0.85	1	<0.50	<0.50	µg/s	17	<18	9	17	<64	<64	< 64	µg/L	<0.003	73	(1) CEQG	1.3	No	No
Nickel	µg/L	2.9	< 1.0	1	2.7	<1.0	<1.0	µg/s	50	<35	10	46	<128	<128	< 128	µg/L	<0.005	25	(1) PWQO	1.025	No	No
Potassium	µg/L	2200	750	1800	2200	1100	1100	µg/s	37996	26261	18049	37722	140903	140903	140903	µg/L	6	5300	(3) Suter and Tsao	1625	No	No
Selenium	µg/L	< 2.0	< 2.0	< 2.0	< 2.0	<2.0	<2.0	µg/s	<35	<70	<20	<34	<256	<256	< 256	µg/L	<0.01	1	(1) CEQG	0.13875	No	No
Silicon	µg/L	2100	590	2000	2000	470	450	µg/s	36269	20659	20054	34293	60204	57642	60204	µg/L	3	260	(4) Background	260	No	No
Silver	µg/L	< 0.10	< 0.10	< 0.10	0.17	<0.10	<0.10	µg/s	<1.7	<3.5	<1.0	2.9	<13	<13	< 13	µg/L	<0.0006	0.1	(1) PWQO	<0.1	No	No
Sodium	µg/L	20000	2000	29000	20000	2200	2200	µg/s	345415	70030	290787	342928	281806	281806	345415	µg/L	15	68000	(3) Suter and Tsao	14500	No	No
Strontium	µg/L	110	30	120	110	24	24	µg/s	1900	1050	1203	1886	3074	3074	3074	µg/L	0.1	2500	(1) FEQG	180	No	No
Tellurium	µg/L	< 1.0	< 1.0	< 1.0	< 1.0	<1.0	<1.0	µg/s	<17.3	<35.0	<10.0	<17.1	<128	<128	< 128	µg/L	<0.005	15.19	(3) Borgmann et al	<1	No	No
Thallium	µg/L	< 0.050	< 0.050	< 0.050	< 0.050	<0.050	<0.050	µg/s	<0.86	<1.75	<0.50	<0.9	<6	<6	< 6	µg/L	<0.0003	0.8	(1) CEQG	<0.05	No	No
Tin	µg/L	< 1.0	< 1.0	< 1.0	< 1.0	<1.0	<1.0	µg/s	<17	<35	<10	<17	<128	<128	< 128	µg/L	<0.005	73	(3) Suter and Tsao	<1	No	No
Titanium	µg/L	18	6.8	5	17	6.5	<5.0	µg/s	311	238	50	291	833	<640	833	µg/L	0.04	100	(3) Borgmann et al	<5	No	No
Tungsten	µg/L	< 1.0	< 1.0	< 1.0	< 1.0	<1.0	<1.0	µg/s	<17	<35	<10	<17	<128	<128	< 128	µg/L	<0.005	30	(2) iPWQO	<1	No	No
Uranium	µg/L	0.13	< 0.10	0.34	0.14	0.1	<0.10	µg/s	2.2	<3.5	3.4	2.4	12.8	<12.8	13	µg/L	0.0005	15	(1) CEQG	0.3675	No	No
Vanadium	µg/L	2.8	1	1.2	2.9	0.88	0.71	µg/s	48	35	12	50	113	91	113	µg/L	0.005	120	(1) FEQG	<0.5	No	No
Zinc	µg/L	510	220	150	510	160	160	µg/s	8808	7703	1504	8745	20495	20495	20495	µg/L	1	30	(1) PWQO	<5	No	No
Zirconium	µg/L	< 1.0	< 1.0	< 1.0	< 1.0	<1.0	<1.0	µg/s	<17	<35	<10	<10	<128	<128	< 128	µg/L	<0.005	4	(2) iPWQO	<1	No	No
Petroleum Hydrocarbons (and BTEX)																						
Benzene	µg/L	< 0.20	< 0.20	< 0.20	< 0.20	<0.20	<0.20	µg/s	<3.5	<7.0	<2.0	<3.4	<25.6	<25.6	< 25.6	µg/L	<0.001	100	(2) iPWQO	-	No	No
Toluene	µg/L	0.22	< 0.20	< 0.20	0.21	<0.20	<0.20	µg/s	3.8	<7.0	<2.0	3.6	<25.6	<25.6	< 25.6	µg/L	<0.001	0.8	(2) iPWQO	-	No	No
Ethylbenzene	µg/L	< 0.20	< 0.20	< 0.20	< 0.20	0.49	0.41	µg/s	<3.5	<7.0	<2.0	<3.4	63	53	62.8	µg/L	0.003	8	(2) iPWQO	-	No	No
o-Xylene	µg/L	0.36	< 0.20	< 0.20	0.38	0.7	0.66	µg/s	6.2	<7.0	<2.0	7	90	85	90	µg/L	0.004	40	(2) iPWQO	-	No	No
m,p-Xylenes	µg/L	0.56	< 0.40	< 0.40	0.55	1.5	1.6	µg/s	9.7	<14.0	<4.0	9	192	205	205	µg/L	0.01	2	(2) iPWQO	-	No	No
Xylenes, Total	µg/L	0.92	< 0.40	< 0.40	0.94	2.2	2.3	µg/s	15.9	<14.0	<4.0	16	282	295	295	µg/L	0.01	2	(2) iPWQO	-	No	No
Petroleum Hydrocarbons - F1 (C6-C10)-BTEX	µg/L	< 25	< 25	< 25	< 25	<25	<25	µg/s	<432	<875	<251	<429	<3202	<3202	< 3202	µg/L	<0.1	<25	(4) Background	<25	No	No
Petroleum Hydrocarbons - F1 (C6-C10)	µg/L	< 25	< 25	< 25	< 25	<25	<25	µg/s	<432	<875	<251	<429	<3202	<3202	< 3202	µg/L	<0.1	<25	(4) Background	<25	No	No
Petroleum Hydrocarbons - F2 (C10-C16)	µg/L	< 100	< 100	< 100	< 100	<100	<100	µg/s	<1727	<3501	<1003	<1715	<12809	<12809	< 12809	µg/L	<0.5	<100	(4) Background	<100	No	No
Petroleum Hydrocarbons - F3 (C16-C34)	µg/L	210	< 200	< 200	230	<200	<200	µg/s	3627	<7003	<2005	<3429	<25619	<25619	< 25619	µg/L	<1	<200	(4) Background	<200	No	No
Petroleum Hydrocarbons - F4 (C34-C50)	µg/L	< 200	< 200	< 200	< 200	<200	<200	µg/s	<3454	<7003	<2005	<3429	<25619	<25619	< 25619	µg/L	<1	<200	(4) Background	<200	No	No

Table A.8d: Screening of Stormwater COPCs for Ecological Health - Lake Water West

		Concentration							Loading							Screening						
Location	Units	Catchment 3						Unit	Catchment 3						Max Loading	Units	Final Concentration in Lake	Screening Criteria		Mean Background in 2015 (LWC-1)	Exceeds Screening Criteria?	Carried Forward as COPC for the EcoRA?
Station ID		MH211							MH211									Selected Screening Level	Source / Basis			
Date		20-Aug-15	28-Oct-15	19-Nov-15	20-Aug-15	11-Jun-16	2016-06-11 (dup)		20-Aug-15	28-Oct-15	19-Nov-15	20-Aug-15	11-Jun-16	2016-06-11 (Dup)								
Radiological																						
Carbon-14	Bq/L	< 20	< 20	< 20	< 20	<20	<20	Bq/s	<345	<700	<201	<343	<2562	<2562	< 2562	Bq/L	<0.1	<0.1	(4) Background	<0.1	No	No
Cesium-134	Bq/L	< 1	< 1	< 1	< 1	<1	<1	Bq/s	<17	<35	<10	<17	<128	<128	< 128	Bq/L	<0.005	<0.1	(4) Background	<0.1	No	No
Cesium-137	Bq/L	< 1	< 1	< 1	< 1	<1	<1	Bq/s	<17	<35	<10	<17	<128	<128	< 128	Bq/L	<0.005	50	(1) PWQO	<0.1	No	No
Cobalt-60	Bq/L	-	< 1	< 1	-	<1	<1	Bq/s	-	<35	<10	-	<128	<128	< 128	Bq/L	<0.005	<0.1	(4) Background	<0.1	No	No
Iodine-131	Bq/L	< 1	< 1	< 1	< 1	<1	<1	Bq/s	<17	<35	<10	<17	<128	<128	< 128	Bq/L	<0.005	10	(1) PWQO	-	No	No
Manganese-54	Bq/L	< 1	-	-	< 1	-	-	Bq/s	<17	-	-	<17	-	-	< 17	Bq/L	<0.0007	--	--	-	No	No
Tritium (HTO)	Bq/L	3520	7080	39600	3480	2930	2930	Bq/s	60793	247906	397074	59669	375314	375314	397074.269	Bq/L	17	7000	(1) PWQO	<4.4	No	No
Zinc-65	Bq/L	< 1	-	-	< 1	-	-	Bq/s	<17	-	-	<17	-	-	< 17	Bq/L	<0.0007	--	--	-	No	No

Notes:

a - PWQO state that alkalinity should not be decreased by more than 25% of the natural concentration

b - 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.

c - There are no ecological protection values for silicon. Silicon is an abundant element in the earth's crust.

d - Maximum value from 2014 Supplementary EMP Study (Ecometrix, 2015)

e - To estimate parameter-dependent guidelines the following values were used: Hardness (100 mg/L), pH (8.0), Total Organic Carbon (0.5 mg/L)

Bold Text	= Exceeds Surface Water Quality Benchmark
-	= No value
--	= No associated screening criteria

References:

PWQO = Ontario Provincial Water Quality Objectives, MOEE 1994, updated July 1998

iPWQO = Interim Ontario Provincial Water Quality Objectives, MOE 1994, update July 1998

CEQG = Canadian Environmental Quality Guidelines, current to September 2021

FEQG = Federal Environmental Quality Guidelines, current to September 2021

Suter and Tsao, (1996). Toxicological Benchmarks for Screening Potential Contaminants of Concern for Effects on Aquatic Biota: 1996 Revision.

Borgmann et al., (2005). Toxicity of Sixty-Three Metals and Metalloids to Hyalella Azteca at Two Levels of Water Hardness.

British Columbia, (2021). British Columbia Working Water Quality Guidelines: Aquatic Life, Wildlife & Agriculture Feb 2021

Table A.9: Screening of Frenchman's Bay Water COPCs for Ecological Health

Analyte	Unit	2015 Mean Background (LWC-1)	Max Observed 2015 Frenchman's Bay Water	Screening Criteria: Selected Screening Level	Screening Criteria: Source / Basis	Exceeds Screening Criteria?	Carried Forward as COPC for the EcoRA?	Notes
General Chemistry								
Alkalinity (Total as CaCO3)	mg/L	93	150	<25% background	(1) PWQO	No	No	Hardness can may affect the transport and behaviour of other contaminants, but are not on their own expected to present risks to ecological receptors.
Ammonia Nitrogen	mg/L	<0.05	<0.05	0.016	(1) CEQG	Yes	No	DL > Screening criteria but parameter was not detected.
Unionized Ammonia, calculated	mg/L	<0.0016	<0.0069	0.019	(1) CEQG	No	No	DL > Screening criteria but parameter was not detected.
Biochemical Oxygen Demand, 5 Day	mg/L	2.25	5	--	See note (b)	No	No	-
Chemical Oxygen Demand	mg/L	5.4	15	--	See note (b)	No	No	-
Conductivity	ms/cm	0.314	0.86	--	See note (b)	No	No	-
Conductivity, field measured	ms/cm	0.259	0.774	--	See note (b)	No	No	-
Hardness, Calcium Carbonate	mg/L	127.5	210	--	See note (b)	No	No	-
Temperature, field measured	C	12.33	23.94	--	See note (b)	No	No	Assessed as a physial stressor
Total Suspended Solids	mg/L	<1-<10	20	5 mg/L above bkgrd	(1) CEQG	No	No	TSS is a water quality parameter, and not a chemical parameter to be assessed for chemical risk.
pH	pH units	7.9025	8.26	6.5 - 8.5	(1) PWQO	No	No	-
pH, field measured	pH units	8.14	8.56	6.5 - 8.5	(1) PWQO	No	No	-
Total Residual Chlorine, field measured	mg/L	<0.0012	<0.0012	0.0005	(1) CEQG	No	No	-
Metals/Metalloids								
Aluminum	mg/L	0.007	0.27	0.1	(1) CEQG	**Yes**	**Yes**	**Max > CEQG**
Aluminum, filtered	mg/L	0.009	0.006	0.1	(1) CEQG	No	No	-
Antimony	mg/L	<0.0005	<0.0005	0.02	(2) iPWQO	No	No	-
Arsenic	mg/L	<0.0010	0.0011	0.005	(1) CEQG	No	No	-
Barium	mg/L	0.02225	0.046	1	(3) BC Working WGG	No	No	-
Beryllium	mg/L	<0.0005	<0.0005	1.1	(1) PWQO	No	No	-
Bismuth	mg/L	<0.001	<0.001	0.02543	(3) Borgmann et al	No	No	-
Boron	mg/L	0.0255	0.042	1.5	(1) CEQG	No	No	-
Cadmium	mg/L	0.0000095	0.00001	0.00016	(1) CEQG	No	No	-
Calcium	mg/L	34	64	11.6	(3) Suter and Tsao	Yes	No	Calcium is a macronutrient for plants and animals; and is not a concern for ecological health.
Chromium	mg/L	<0.0050	<0.0050	0.0089	(1) PWQO, CEQG	No	No	-
Cobalt	mg/L	<0.0005	<0.0005	0.001	(1) FEQG	No	No	-
Copper	mg/L	<0.0010	0.0021	0.00236	(1) CEQG	No	No	-
Iron	mg/L	<0.1	0.56	0.3	(1) PWQO, CEQG	**Yes**	**Yes**	**Max > PWQO, CEQG**
Lead	mg/L	<0.0005	0.00092	0.0028	(1) FEQG	No	No	-
Lithium	mg/L	<0.005	<0.005	0.014	(3) Suter and Tsao	No	No	DL > Screening criteria but parameter was not detected.
Magnesium	mg/L	8.775	11	8.2	(3) Suter and Tsao	No	No	-
Manganese	mg/L	<0.0020	0.08	0.37	(1) CEQG	No	No	-
Mercury	mg/L	0.00001	<0.0001	0.000026	(1) CEQG	Yes	No	Not detected in Frenchman's Bay (see note f)
Molybdenum	mg/L	0.0013	0.0013	0.073	(1) CEQG	No	No	Equal to background
Nickel	mg/L	0.001025	0.0013	0.025	(1) PWQO	No	No	-
Potassium	mg/L	1.625	2.3	5.3	(3) Suter and Tsao	No	No	-
Selenium	mg/L	0.00013875	0.00022	0.001	(1) CEQG	No	No	-
Silicon	mg/L	0.26	1.4	0.26	(4) Background	Yes	No	Widespread element with low intrinsic toxicity
Silver	mg/L	<0.0001	<0.0001	0.0001	(1) PWQO	No	No	-
Sodium	mg/L	14.5	91	68	(3) Suter and Tsao	**Yes**	**Yes**	**Max > Toxicity Benchmark**
Strontium	mg/L	0.18	0.28	2.5	(1) FEQG	No	No	-
Tellurium	mg/L	<0.0010	<0.0010	0.01519	(3) Borgmann et al	No	No	-
Thallium	mg/L	<0.000050	<0.000050	0.0008	(1) CEQG	No	No	-
Tin	mg/L	<0.0010	<0.0010	0.073	(3) Suter and Tsao	No	No	-
Titanium	mg/L	<0.005	0.013	0.1	(3) Borgmann et al	No	No	-
Tungsten	mg/L	<0.0010	<0.0010	0.03	(2) iPWQO	No	No	-
Uranium	mg/L	0.0003675	0.00045	0.015	(1) CEQG	No	No	-
Vanadium	mg/L	<0.0005	0.0013	0.12	(1) FEQG	No	No	-
Zinc	mg/L	<0.0050	0.0074	0.03	(1) PWQO	No	No	-
Zirconium	mg/L	<0.0010	<0.0010	0.004	(2) iPWQO	No	No	-

Table A.9: Screening of Frenchman's Bay Water COPCs for Ecological Health

Analyte	Unit	2015 Mean Background (LWC-1)	Max Observed 2015 Frenchman's Bay Water	Screening Criteria: Selected Screening Level	Screening Criteria: Source / Basis	Exceeds Screening Criteria?	Carried Forward as COPC for the EcoRA?	Notes
Petroleum Hydrocarbons								
Petroleum Hydrocarbons - F1 (C6-C10)-BTEX	mg/L	<0.025	<0.025	0.025	(4) Background	No	No	-
Petroleum Hydrocarbons - F1 (C6-C10)	mg/L	<0.025	<0.025	0.025	(4) Background	No	No	-
Petroleum Hydrocarbons - F2 (C10-C16)	mg/L	<0.1	<0.1	0.1	(4) Background	No	No	-
Petroleum Hydrocarbons - F3 (C16-C34)	mg/L	<0.2	<0.2	0.2	(4) Background	No	No	-
Petroleum Hydrocarbons - F4 (C34-C50)	mg/L	<0.2	<0.2	0.2	(4) Background	No	No	-
Other								
Morpholine	mg/L	<0.004	<0.004	0.004	(2) iPWQO	No	No	-
Radionuclides								
Tritium	Bq/L	<4.4	16.2	--	--	-	-	Assessed quantitatively for public interest purposes
C-14	Bq/L	<0.1	<0.1	--	--	-	-	
Co-60	Bq/L	<0.1	<0.1	--	--	-	-	
Cs-134	Bq/L	<0.1	<0.1	--	--	-	-	
Cs-137	Bq/L	<0.1	<0.1	--	--	-	-	

Notes:

a - PWQO state that alkalinity should not be decreased by more than 25% of the natural concentration

b - 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.

c - There are no ecological protection values for silicon. Silicon is an abundant element in the earth's crust.

d - Maximum value from 2014 Supplementary EMP Study (Ecometrix, 2015)

e - To estimate parameter-dependent guidelines the following values were used: Hardness (100 mg/L), pH (8.0), Total Organic Carbon (0.5 mg/L)

f - The detection limit for mercury was 0.0001 mg/L for the July 2015 Frenchman's Bay sampling. A lower detection limit of 0.00001 mg/L was used for the August 2015 sampling (only lake water samples were collected in August 2015).

Bold Text	= Exceeds Surface Water Quality Benchmark
-	= No value
--	= No associated screening criteria

References:

PWQO = Ontario Provincial Water Quality Objectives, MOEE 1994, updated July 1998

iPWQO = Interim Ontario Provincial Water Quality Objectives, MOE 1994, update July 1998

CEQG = Canadian Environmental Quality Guidelines, current to September 2021

FEQG = Federal Environmental Quality Guidelines, current to September 2021

Suter and Tsao, (1996). Toxicological Benchmarks for Screening Potential Contaminants of Concern for Effects on Aquatic Biota: 1996 Revision.

Borgmann et al., (2005). Toxicity of Sixty-Three Metals and Metalloids to Hyalella Azteca at Two Levels of Water Hardness.

British Columbia, (2021). British Columbia Working Water Quality Guidelines: Aquatic Life, Wildlife & Agriculture Feb 2021

Table A.10: Screening of Frenchman's Bay Sediment COPCs for Ecological Assessment

Analyte	Unit	Max Observed 2015 Sediment	Screening: Selected Screening Level	Screening: Source / Basis	Exceeds Screening Criteria?	Carried Forward as COPC?	Notes
General Chemistry							
Total Organic Carbon	µg/g dw	**100000**	10000	(1) PSQG	**Yes**	**Yes**	-
Gravel	%	-	-	-	-	-	-
Sand	%	-	-	-	-	-	-
Silt	%	-	-	-	-	-	-
Clay	%	-	-	-	-	-	-
Moisture	%	-	-	-	-	-	-
Metals/Metalloids							
Aluminum	µg/g dw	13000	58030	(2) Jones et al 1997	No	No	-
Antimony	µg/g dw	1	2	(2) Long and Morgan 1991	No	No	-
Arsenic	µg/g dw	5	6	(1) CSQG	No	No	-
Barium	µg/g dw	110	264	(3) L. Ontario Bkgrd	No	No	-
Beryllium	µg/g dw	0.58	1.17	(3) L. Ontario Bkgrd	No	No	-
Bismuth	µg/g dw	<1.0	<0.5	(3) L. Ontario Bkgrd	**Yes**	**Yes**	See Appendix E
Boron	µg/g dw	25	7.1	(3) L. Ontario Bkgrd	**Yes**	**Yes**	See Appendix E
Cadmium	µg/g dw	0.75	0.60	(1) PSQG, CSQG	**Yes**	**Yes**	See Appendix E
Calcium	µg/g dw	130000	107576	(3) L. Ontario Bkgrd	Yes	No	Component of sediment; not toxic
Chromium	µg/g dw	31	26	(1) PSQG	**Yes**	**Yes**	see Appendix E
Cobalt	µg/g dw	8	50	(1) PSQG	No	No	-
Copper	µg/g dw	74	16	(1) PSQG	**Yes**	**Yes**	See Appendix E
Iron	µg/g dw	21000	20000	(1) PSQG	**Yes**	**Yes**	See Appendix E
Lead	µg/g dw	43	31	(1) PSQG	**Yes**	**Yes**	see Appendix E
Magnesium	µg/g dw	9600	9600	(3) L. Ontario Bkgrd	No	No	-
Manganese	µg/g dw	660	460	(1) PSQG	**Yes**	**Yes**	see Appendix E
Mercury	µg/g dw	0.08	0.2	(1) CSQG	No	No	-
Molybdenum	µg/g dw	1	13.8	(2) Thompson et al 2005	No	No	-
Nickel	µg/g dw	23	16	(1) PSQG	**Yes**	**Yes**	see Appendix E
Phosphorus	µg/g dw	1500	600	(1) PSQG	**Yes**	**Yes**	see Appendix E
Potassium	µg/g dw	1900	8494	(3) L. Ontario Bkgrd	No	No	-
Selenium	µg/g dw	1.10	1.9	(2) Thompson et al 2005	No	No	-
Silver	µg/g dw	0.25	0.5	(1) PSQG	No	No	-
Sodium	µg/g dw	590	590	(3) L. Ontario Bkgrd	No	No	-
Strontium	µg/g dw	220	220	(3) L. Ontario Bkgrd	No	No	-
Thallium	µg/g dw	0.26	0.17	(3) L. Ontario Bkgrd	**Yes**	**Yes**	see Appendix E
Tin	µg/g dw	5	3	(3) L. Ontario Bkgrd	**Yes**	**Yes**	see Appendix E
Uranium	µg/g dw	0.68	104.4	(2) Thompson et al 2005	No	No	-
Vanadium	µg/g dw	29	35.2	(2) Thompson et al 2005	No	No	-
Zinc	µg/g dw	230	120	(1) PSQG	**Yes**	**Yes**	see Appendix E
Radionuclides							
C-14	Bq/kg-C dw	272	--	--	-	-	Assessed quantitatively for public interest purposes
Co-60	Bq/kg dw	<1	--	--	-	-	
Cs-134	Bq/kg dw	<3.3	--	--	-	-	
Cs-137	Bq/kg dw	3	--	--	-	-	

Notes:

Bold Text	= Exceeds Sediment Quality Benchmark
-	= No value
--	= No associated screening criteria

Sources:

PSQG = Ontario Provincial Sediment Quality Guidelines, Lowest Effect Level. Also incudes additional parameters carried over from the Open Water Disposal Guidelines (cobalt, silver)

CSQG = CCME Canadian Sediment Quality Guidelines for the Protection of Aquatic Life - Interim Freshwater Sediment Quality Guidelines (ISQGs)

Jones, Suter, and Hull (1997). Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Sediment - Associated Biota: 1997 Revision. The probable effect concentration was adopted.

P. A. Thompson, J. Kurias and S. Mihok. 2005. Derivation and use of sediment quality guidelines for ecological risk assessment of metals and radionuclides released to the environment from uranium mining and milling activities in Canada. Environmental Monitoring and Assessment (110): 71-85. Weighted method was adopted in the table.

Long, E. R. and Morgan L. G. (1991), The Potential for Biological Effects of Sediment-Sorbed Contaminants Tested in the National Status and Trends Program. NOAA. August.

L. Ontario background = OPG, 2009 (95th Percentile of Regional Lake Ontario Sediment)

Table A.11: Screening of Ditch Landfill COPCs for Ecological Assessment

Parameter	Units	Ditch 6 (2010)	Ditch 6 (2012)	Max Concentration in Ditch 6	Screening Criteria		Exceeds Screening Criteria?	Carried Forward as COPC?	Notes
					Selected Screening Level	Source / Basis			
Alkalinity (as CaCO3)	mg/L	217	364	364	--	See note (a)	-	-	-
Biological Oxygen Demand	mg/L	6.5	< 2	6.5	--	See note (b)	-	-	-
Dissolved Organic Carbon	mg/L	6	9.8	9.8	--	See note (b)	-	-	-
Hardness (as CaCO3)	mg/L	752	587	752	--	See note (b)	-	-	-
pH	pH Units	7.57	7.75	7.75	6.5 - 8.5	(1) PWQO	No	No	-
TSS	mg/L	25	5.5	25	--	See note (b)	-	-	-
Calcium	mg/L	229	168	229	1000	(1) CEQG, livestock	No	No	-
Copper	mg/L	0.003	<0.01	<0.01	0.004	(1) CEQG, PAL	No	No	-
Phosphorus	mg/L	0.04	<0.2	<0.2	0.01	(1) PWQO	Yes	No	No (exceeds PWQO but not considered toxicity issue)
Zinc	mg/L	0.0070	<0.005	<0.005	0.03	(1) PWQO	No	No	-
Phenol	mg/L	<0.002	<0.002	<0.002	0.004	(1) CEQG, PAL	No	No	-
Sulphate	mg/L	328	245	328	429	(2) BC MOE	No	No	-

Notes:

a - PWQO state that alkalinity should not be decreased by more than 25% of the natural concentration but this is not applicable for the landfill.

b - Risk-based guidelines are not applicable to water quality parameters such as conductivity, biological oxygen demand, chemical oxygen demand, and total suspended solids and therefore are excluded from screening.

Bold Text	= Exceeds Sediment Quality Benchmark
-	= No value
--	= No associated screening criteria

References:

PWQO = Ontario Provincial Water Quality Objectives, MOEE 1994, updated July 1998

CEQG = Canadian Environmental Quality Guidelines, Protection of Freshwater Aquatic Life (PAL) with exception of calcium and sulphate where Agriculture-Livestock values are used, current to September 2021

BC MOE = British Columbia Ministry of Environment Ambient Water Quality Guideline for Sulphate (2013)

Table A.12: Screening of Soil COPCs for Ecological Risk Assessment

Parameter	Unit	Max Soil Concentration	Soil Screening Level		Exceeds Screening Level?	Carried Forward as COPC?	Notes
			Selected Screening Level	Source / Basis			
Inorganics							
Conductivity	ms/cm	1.2	1.4	MECP Eco CVs	No	No	-
Cyanide (free)	ug/g	0.33	0.11	MECP Eco CVs	**Yes**	**Yes**	**Max > MECP Component Value**
Moisture, Percent	%	20	--	--	No	No	-
pH	pH units	8.07	6-9	MECP Eco CVs	No	No	-
Sodium Adsorption Ratio	-	11	12	MECP Eco CVs, CCME SQG	No	No	-
Metals							
Antimony	ug/g	9.7	40	MECP Eco CVs	No	No	-
Arsenic	ug/g	58	26	CCME SQG	**Yes**	**Yes**	**Max > SQG_E**
Barium	ug/g	140	670	MECP Eco CVs	No	No	-
Beryllium	ug/g	0.79	8	MECP Eco CVs	No	No	-
Boron	ug/g	12	120	MECP Eco CVs	No	No	-
Boron, Hot Water Soluble	ug/g	0.42	2	MECP Eco CVs	No	No	-
Cadmium	ug/g	1.7	1.9	MECP Eco CVs	No	No	-
Chromium	ug/g	44	87	CCME SQG	No	No	-
Cobalt	ug/g	67	80	MECP Eco CVs	No	No	-
Copper	ug/g	830	230	MECP Eco CVs	**Yes**	**Yes**	**Max > MECP Component Value**
Hexavalent Chromium	ug/g	<0.2	8	MECP Eco CVs	No	No	-
Lead	ug/g	230	32	MECP Eco CVs	**Yes**	**Yes**	**Max > MECP Component Value**
Mercury	ug/g	<0.05	20	MECP Eco CVs	No	No	-
Molybdenum	ug/g	16	40	MECP Eco CVs, CCME SQG	No	No	-
Nickel	ug/g	23	89	CCME SQG	No	No	-
Selenium	ug/g	2	2.9	CCME SQG	No	No	-
Silver	ug/g	0.53	40	MECP Eco CVs, CCME SQG	No	No	-
Thallium	ug/g	0.22	1	CCME SQG	No	No	-
Uranium	ug/g	0.89	33	MECP Eco CVs	No	No	-
Vanadium	ug/g	41	18	MECP Eco CVs	No	No	-
Zinc	ug/g	3200	340	MECP Eco CVs	**Yes**	**Yes**	**Max > MECP Component Value**
Petroleum Hydrocarbons							
Petroleum Hydrocarbons - F1 (C6-C10)	ug/g	< 10	320	MECP Eco CVs	No	No	-
Petroleum Hydrocarbons - F1 (C6-C10)-BTEX	ug/g	< 10	320	MECP Eco CVs	No	No	-
Petroleum Hydrocarbons - F2 (C10-C16)	ug/g	< 10	260	MECP Eco CVs	No	No	-
Petroleum Hydrocarbons - F3 (C16-C34)	ug/g	1100	1700	MECP Eco CVs	No	No	-
Petroleum Hydrocarbons - F4 (C34-C50)	ug/g	1500	3300	MECP Eco CVs	No	No	-
Petroleum Hydrocarbons - F4 Gravimetric	ug/g	5700	3300	MECP Eco CVs	**Yes**	**Yes**	**Max > MECP Component Value**

Table A.12: Screening of Soil COPCs for Ecological Risk Assessment

Parameter	Unit	Max Soil Concentration	Soil Screening Level		Exceeds Screening Level?	Carried Forward as COPC?	Notes
			Selected Screening Level	Source / Basis			
VOCs							
1,1,1,2-Tetrachloroethane	ug/g	< 0.050	4400	MECP Eco CVs	No	No	-
1,1,1-Trichloroethane	ug/g	< 0.050	35	MECP Eco CVs	No	No	-
1,1,2,2-Tetrachloroethane	ug/g	< 0.050	6700	MECP Eco CVs	No	No	-
1,1,2-Trichloroethane	ug/g	< 0.050	160	MECP Eco CVs	No	No	-
1,1-Dichloroethane	ug/g	< 0.050	17	MECP Eco CVs	No	No	-
1,1-Dichloroethene	ug/g	< 0.050	100	MECP Eco CVs	No	No	-
1,2-Dibromoethane	ug/g	< 0.050	2000	MECP Eco CVs	No	No	-
1,2-Dichlorobenzene	ug/g	< 0.050	6.8	MECP Eco CVs	No	No	-
1,2-Dichloroethane	ug/g	< 0.050	29	MECP Eco CVs	No	No	-
1,2-Dichloropropane	ug/g	< 0.050	50	MECP Eco CVs	No	No	-
1,3-Dichlorobenzene	ug/g	< 0.050	9.6	MECP Eco CVs	No	No	-
1,3-Dichloropropene, Total	ug/g	< 0.050	50	MECP Eco CVs	No	No	-
1,4-Dichlorobenzene	ug/g	< 0.050	7.2	MECP Eco CVs	No	No	-
2-Butanone (Methyl Isobutyl Ketone)	ug/g	< 0.50	70	MECP Eco CVs	No	No	-
4-Methyl-2-pentanone (Methyl Isobutyl Ketone)	ug/g	< 0.50	5100	MECP Eco CVs	No	No	-
Acetone	ug/g	< 0.50	56	MECP Eco CVs	No	No	-
Benzene	ug/g	< 0.020	180	MECP Eco CVs	No	No	-
Bromodichloromethane	ug/g	< 0.050	5500	MECP Eco CVs	No	No	-
Bromoform	ug/g	< 0.050	11000	MECP Eco CVs	No	No	-
Bromomethane	ug/g	< 0.050	7300	MECP Eco CVs	No	No	-
Carbon Tetrachloride	ug/g	< 0.050	12	MECP Eco CVs	No	No	-
Chlorobenzene	ug/g	< 0.050	12	MECP Eco CVs	No	No	-
Chloroform	ug/g	< 0.050	68	MECP Eco CVs	No	No	-
cis-1,2-Dichloroethene	ug/g	< 0.050	940	MECP Eco CVs	No	No	-
cis-1,3-Dichloropropene	ug/g	< 0.030	50	MECP Eco CVs	No	No	-
Dibromochloromethane	ug/g	< 0.050	10000	MECP Eco CVs	No	No	-
Dichlorodifluoromethane	ug/g	< 0.050	80	MECP Eco CVs	No	No	-
Ethylbenzene	ug/g	< 0.020	300	MECP Eco CVs	No	No	-
Methyl tert-Butyl Ether	ug/g	< 0.050	50	MECP Eco CVs	No	No	-
Methylene Chloride	ug/g	< 0.050	1.6	MECP Eco CVs	No	No	-
n-Hexane	ug/g	< 0.050	1500	MECP Eco CVs	No	No	-
Styrene	ug/g	< 0.050	34	MECP Eco CVs	No	No	-
Tetrachloroethene	ug/g	< 0.050	34	MECP Eco CVs	No	No	-
Toluene	ug/g	< 0.020	500	MECP Eco CVs	No	No	-
trans-1,2-Dichloroethene	ug/g	< 0.050	940	MECP Eco CVs	No	No	-
trans-1,3-Dichloropropene	ug/g	< 0.040	50	MECP Eco CVs	No	No	-
Trichloroethene	ug/g	< 0.050	200	MECP Eco CVs	No	No	-
Trichlorofluoromethane	ug/g	< 0.050	32	MECP Eco CVs	No	No	-
Vinyl Chloride	ug/g	< 0.020	6.8	MECP Eco CVs	No	No	-
Xylenes, Total	ug/g	< 0.020	350	MECP Eco CVs	No	No	-

Table A.12: Screening of Soil COPCs for Ecological Risk Assessment

Parameter	Unit	Max Soil Concentration	Soil Screening Level		Exceeds Screening Level?	Carried Forward as COPC?	Notes
			Selected Screening Level	Source / Basis			
Semi-VOCs							
1- & 2-Methylnaphthalene	ug/g	0.018	3600	MECP Eco CVs	No	No	-
1-Methylnaphthalene	ug/g	0.0094	3600	MECP Eco CVs	No	No	-
2-Methylnaphthalene	ug/g	0.0083	3600	MECP Eco CVs	No	No	-
Acenaphthene	ug/g	< 0.0050	2800	MECP Eco CVs	No	No	-
Acenaphthylene	ug/g	< 0.0050	2900	MECP Eco CVs	No	No	-
Anthracene	ug/g	0.012	32	MECP Eco CVs	No	No	-
Benzo [b,j] fluoranthene	ug/g	0.11	7600	MECP Eco CVs	No	No	-
Benzo[a]anthracene	ug/g	0.065	1	MECP Eco CVs	No	No	-
Benzo[a]pyrene	ug/g	0.052	72	MECP Eco CVs	No	No	-
Benzo[g,h,i]perylene	ug/g	0.031	13	MECP Eco CVs	No	No	-
Benzo[k]fluoranthene	ug/g	0.022	15	MECP Eco CVs	No	No	-
Chrysene	ug/g	0.064	14	MECP Eco CVs	No	No	-
Dibenzo[a,h]anthracene	ug/g	0.0066	7600	MECP Eco CVs	No	No	-
Fluoranthene	ug/g	0.17	180	MECP Eco CVs	No	No	-
Fluorene	ug/g	< 0.0050	2800	MECP Eco CVs	No	No	-
Indeno[1,2,3-cd]pyrene	ug/g	0.036	0.76	MECP Eco CVs	No	No	-
Naphthalene	ug/g	< 0.0050	22	MECP Eco CVs	No	No	-
Phenanthrene	ug/g	0.068	12	MECP Eco CVs	No	No	-
Pyrene	ug/g	0.12	7700	MECP Eco CVs	No	No	-
Styrene	ug/g	< 0.050	34	MECP Eco CVs	No	No	-
Diethylene Glycol	mg/kg	< 10	6200	--	No	No	-
Ethylene Glycol	mg/kg	< 10	960	CCME SQG	No	No	-
Propylene Glycol	mg/kg	< 10	6210	interim SQG	No	No	-
Total Glycols	mg/kg	< 10	--	--	No	No	-

Notes:

Bold Text	= Exceeds screening criteria
-	= No value
--	= No associated screening criteria

References:

MECP Eco CVs = Lowest of the Plants & Soil Organisms or Mammals & Birds Component Values (MOE 2011)

CCME SQG = Canadian Soil Quality Guidelines

Appendix B Ecological Receptor Profiles

One of the key considerations, which defines the scope of a risk assessment, is the selection of ecological receptors. In selecting ecological receptors, it is important to identify plants and animals that are likely to be most exposed to the effects of the project. As it is not possible to evaluate all ecological species at a site, representative VECs are generally selected based on several criteria as discussed in Section 4.1.1 of the main report.

This appendix details the aquatic and terrestrial ecological receptors (groups or species) selected for the assessment.

B.1 Aquatic Biota

B.1.1 Benthic Invertebrates

Benthic invertebrates live and feed within sediments and provide a sediment to fish pathway link and between aquatic and terrestrial ecosystems. Many species feed on decaying organic matter and thereby form an important link between the decomposer and primary consumer levels. Small crustaceans such as the benthic amphipod *Diporeia* spp. and worms (oligochaetes) have historically dominated the open water benthic communities of Lake Ontario. Representatives of the more environmentally sensitive groups such as Ephemeroptera and Trichoptera are generally rare. Most of the dominant taxa had higher abundances at sites within or close to the thermal plumes than at reference sites. In shallow areas, gastropods and bivalves have low relative abundances presumably due to wave abrasion and/or unsuitable substrates at shallow locations. Appearance of chironomid, amphipod and oligochaete increased in the shallows (1-m depth) in the vicinity of the discharge channels where the algae, *Cladophora*, are present.

Aquatic invertebrates are represented by the benthic invertebrates in the ecological model.

B.1.2 Aquatic Plants

B.1.2.1 Narrow-leaved Cattail

The Narrow-leaved Cattail (*Typha angustifolia*) is a native emergent wetland species, growing to over 1 m tall. It is commonly found in the northern hemisphere in marshes, ponds, and ditches (Newmaster et al., 1997). Cattails are a good source of material for nest building. Cattails are used by the Red-winged Blackbird and Muskrat for nesting, and as feed for the Muskrat.

Catland marsh communities are dominant throughout Hydro Marsh and Frenchman's Bay and are also known to grow intermittently in drainage ditches near PNGS (OPG, 2018; SENES, 2007). The Narrow-leaved Cattail is listed as a native and common species in flora inventories for the PN site as recently as 2020 (Beacon, 2020).

B.1.3 Amphibians and Reptiles

Amphibians (class: Amphibia) typically inhabit a wide variety of habitats with most species bridging terrestrial and aquatic ecosystems during their life cycle. Common animals within the class include frogs and salamanders. Amphibians rely on surface water for reproduction as larvae are typically born in water. The young generally undergo metamorphosis from larva with gills to an adult air-breathing form with lungs. With their complex reproductive needs and permeable skins, amphibians are often used as ecological indicators.

Reptiles (class: Reptilia) are cold blooded animals with scales or scutes rather than fur and feathers like mammals and birds. Common animals within the class include turtles, snakes and lizards. Most reptiles are oviparous (egg-laying) but do not require water bodies in which to breed.

B.1.3.1 Midland Painted Turtle

Midland Painted Turtle (*Chrysemys picta marginata*) is the most common turtle species in Ontario. There are three sub-species of the midland painted turtle, two of which are found in Ontario. Painted turtles inhabit waterbodies, such as ponds and marshes that provide abundant basking sites and aquatic vegetation. Northern populations of painted turtles may take up to five years to reach sexual maturity. Reproducing females lay eggs in May to early July. Nests are dug in loamy or sandy soils in sunny areas. Hatchlings may emerge in the fall but may overwinter in the nest and emerge the following spring. Painted turtles are opportunistic feeders and eat algae, invertebrates, fish, frogs, carrion and vegetation.

Habitat for Midland Painted Turtle is available in shallow water and marshes of Hydro Marsh and Frenchman's Bay. As of April 2018 it is designated as a species of "Special Concern" under COSEWIC. It is listed as a common species in the most recent amphibian and reptile inventory for the PN site in 2020 (Beacon, 2020).

B.1.3.2 Northern Leopard Frog

The Northern Leopard Frog (*Lithobates pipiens*) is a medium sized, semi terrestrial frog (family: Ranidae). Breeding typically occurs in permanent and semi-permanent shallow, open wetlands that are typically no deeper than 2.0 m in depth, are neutral pH and lack fish (COSEWIC, 2009). The eggs hatch within a period of 9 days and metamorphosis occurs approximately 60 to 90 days after hatching. During the tadpole stage, which is a sensitive life stage, the exposure of tadpoles and fish to constituents of potential concern (COPCs) is expected to be similar (i.e., gills for breathing, absorption through skin, similar feeding habits).

Northern Leopard Frog is listed as an uncommon species in the most recent amphibian and reptile inventory for the PN site in 2020 (Beacon, 2020).

B.1.4 Benthic Fish

B.1.4.1 American Eel

The American Eel (*Anguilla rostrata*) is a freshwater species found on the eastern coast of North America and enter Ontario through the St. Lawrence River and Lake Ontario. The eel has a snake-like body and a dorsal fin that extends from half-way down the length of its back to the underside of its body. At maturity, eel range from 75 to 100 centimetres (cm) in length and weigh one to three kilograms. American Eel have a complex life cycle, which begins with breeding in the Sargasso Sea in the Atlantic Ocean. Young eels migrate to inland streams where they proceed to feed and mature in freshwater bodies for 10 to 25 years, before returning to the

Sargasso Sea to spawn. The majority of American Eel found in Ontario are large, highly fecund (egg-laden) females. The eel is an important indicator of ecosystem health and is a top predator. The American Eel is designated an endangered species and is protected under the Provincial *Endangered Species Act, 2007*. The American Eel is designated as "threatened" under COSEWIC.

American Eel is listed as a rare native species in the most recent Species List for the PN site in 2020 (Beacon, 2020). It is subject to impingement concerns. In 2020, OPG held permits for species protection or recovery issued under the authority of clause 17(2)(b) of the Endangered Species Act; impinged individuals are reported to MNRF (OPG, 2021).

B.1.4.2 Brown Bullhead

Brown Bullhead (*Ameriurus nebulosus*) is a medium sized member of the catfish family. Brown Bullheads are found in both fresh and brackish waters. They generally inhabit lakes, ponds, impoundments, and low-gradient streams, with shallow water and muddy bottoms. This warm water species is a benthic dweller. It can tolerate lower oxygen levels and higher water temperatures than most other fish species. Brown Bullhead do not migrate seasonally or to breed. Brown Bullheads average 230 to 305 mm in length. A typical adult weighs approximately 454 g but may reach as much as 1.8 kg. Brown Bullheads spawn in the late spring. One or both parents excavate a shallow nest in mud or sandy substrate near the cover of logs, rocks, or vegetation, in water less than 0.6 m deep. Bullheads lay between 2,000 and 10,000 eggs in an adhesive cluster. Both parents guard the eggs and aerate them by fanning, physically stirring them up, and taking them into the mouth and spitting them back out. Larvae stay within the nest under the protection of the parents for their first week. After leaving the nest larvae remain in dense schools until they reach approximately 50 mm. Brown Bullheads are opportunistic nocturnal bottom feeders, consuming a variety of plant, animal, and detrital foods. Juveniles are primarily carnivorous, and feed mostly on invertebrates, as well as eggs and larvae of other fish. Leeches, mollusks, fish eggs, and frogs are also common foods of adults. Brown Bullhead are able to digest and utilize filamentous algae and may consume large amounts of this food source (US EPA, n.d.).

Brown Bullhead was listed on the most recent Species List for the PN site in 2020 (Beacon, 2020).

B.1.4.3 Round Whitefish

The Round Whitefish (*Prosopium cylindraceum*) is a coldwater lake fish. Spawning migrations may be undertaken by some Round Whitefish populations. Adults typically weigh between 454 g and 1360 g. Spawning occurs along lake and stream shorelines in late fall or early winter in southern Canada over gravel shoals or river mouths. Round Whitefish are shallow water bottom feeders. Females lay and average of 5,000 to 12,000 eggs. Round Whitefish hatch as sac fry in March to May and remain on the bottom, seeking shelter in rubble and boulders. Older juveniles, age 1 and 2, live in the same areas as adults but in shallower water and tend to move into deeper and faster water as they grow. Round Whitefish eat a variety of invertebrates including mayfly larvae, chironomid larvae, small mollusks, crustaceans, fish, and fish eggs. Fish in lakes may eat more molluscs and small crustaceans than those in rivers (DFO, 2007; IF&W, 2001).

Round Whitefish was listed in the most recent Species List for the PN site in 2020 as a native species that is uncommon (Beacon, 2020), but is of particular interest due to their potential sensitivity to thermal stressors.

B.1.4.4 White Sucker

White Sucker (*Catostomus commersonni*) is a freshwater fish found in lakes and streams across North America. It is a benthic fish that resides mainly in shallow, warm waters. The White Sucker spawns in spring, April or May, in moderate to swift riffles, in gravelly and stony areas, when the water temperature is above 4°C. Spawning may also take place in the shallow water of lakes. Females randomly scatter 30,000 to 130,000 eggs over the spawning grounds. Fry (1.2 cm in length) feed primarily on plankton and other small free-floating invertebrates. When the White Sucker reaches a length of about 1.6 to 1.8 cm, it begins benthic. White Sucker are preyed upon by birds, fishes, lamprey and mammals. In this assessment, white suckers are assumed to spend half of their time at the sediment surface and the other half immersed in the water (Ontario Fish Species, n.d.).

White Sucker was listed in the most recent Species List for the PN site in 2020 as a common native species (Beacon, 2020).

B.1.5 Pelagic Fish

B.1.5.1 Emerald Shiner

Emerald Shiner (*Notropis atherinoides*) is a member of the minnow family. Emerald Shiner are native to Lake Ontario and relatively uncommon near the PN Site, potentially due to competition and predation from introduced species such as alewives. Emerald Shiners exhibit schooling behaviour, and populations have the potential to fluctuate widely in abundance from year to year. Adult Emerald Shiners average between 6 to 10 cm in length, weighing between 2 to 9g. Spawning takes place in open substrate, usually between June and August when water temperature reaches 20 to 24 °C. Emerald Shiner consume insect larvae, zooplankton and other aquatic microorganisms, and also represent a food source for piscivorous fish and birds.

Emerald shiner was listed in the most recent Species List for the PN site in 2020 as an uncommon native species (Beacon, 2020).

B.1.5.2 Lake Trout

Lake Trout (*Salvelinus namaycush*) is a freshwater char. Lake Trout mainly reside in deep lakes in northern North America where the water is cold and oxygen-rich. In spring, lake trout are widely dispersed in the shallow waters of their habitat but, as soon as the water warms they migrate to deeper and colder water. Adults are generally 38 to 52 cm in length and have an average weight of 4.5 kg. In general, Lake Trout spawn on rocky reefs or shoals in the fall. Spawning takes place at night during which the eggs are scattered over the rocky bottom. The eggs remain among the rocks for weeks and hatch the following spring. Within a month or so after hatching, the young Lake Trout usually seek deeper water and are thought to be reclusive, plankton feeders during their first few years of life. The Lake Trout's diet varies depending on the season; in the summer months they become more planktivorous and during the cooler months, they become piscivorous (DFO, 2013b).

Lake Trout was listed in the most recent Species List for the PN site in 2020 as an uncommon native species (Beacon, 2020).

B.1.5.3 Northern Pike

Northern Pike (*Esox lucius*) is a freshwater species found throughout the northern hemisphere. Pike are found in sluggish streams and shallow, weedy places in lakes, as well as in cold, clear, rocky waters. Pike can grow to large sizes, but typically are 46 to 76 cm in length and weigh 0.9-2.3 kg (DFO, 2013a). Pike reproduce in areas with rich submersible vegetation nearby. Pike are known to spawn in spring when the water temperature first reaches 9°C. After mating, males tend to stay in the area for a few extra weeks. Pike are typically solitary ambush predators. Young pike feed on small invertebrates and quickly move on to bigger prey. When the body length is 4 to 8 cm they start feeding on small fish.

Northern Pike was listed in the most recent Species List for the PN site in 2020 as a scarce native species (Beacon, 2020).

B.1.5.4 Smallmouth Bass

Smallmouth Bass (*Micropterus dolomieui*) is found in the Great Lakes watershed, St. Lawrence River, and northward beyond Lake Nipissing (Ontario MNRF, 2015). It prefers rocky lakes and rivers. Smallmouth Bass concentrate around shoreline rocks and points as well as offshore shoals, often in deep water. Adults have an average weight of 1 to 1.4 kg. Sexual maturity is generally attained in males in their third to fifth year and in females in their fourth to sixth year. Smallmouth Bass spawn in June. Females may lay up to 21,100 eggs. After spawning, the males guard the nest. Larval and young smallmouth bass feed on suspended zooplankton then on small insects and crustaceans following dispersal from nesting territories. Adults eat aquatic insects, large crustaceans, and small fish (Funnell, 2012). Smallmouth Bass is a good natural indicator of a healthy environment.

Smallmouth Bass was listed in the most recent Species List for the PN site in 2020 as a common native species (Beacon, 2020).

B.1.5.5 Walleye

Walleye (*Sander vitreus*) is the largest member of the perch family. The Walleye is native to the freshwaters of North America. The Walleye is a cool-water species that prefers turbid waters in either large, shallow lakes or rivers. Adults are generally 33 to 51 cm in length, with an average weight of 0.45 to 1.4 kg. Walleye spawn in the spring or early summer. Adults migrate to the rocky areas in white water below impassable falls and dams in rivers, or boulder to coarse-gravel shoals of lakes. Spawning takes place at night and the eggs fall into crevices in the rocky substrate. The eggs hatch in 12 to 18 days and by 10 to 15 days after hatching, the young disperse into the upper levels of open water. As the Walleye increases in size, its diet shifts from invertebrates to fishes (DFO, 2013c).

Walleye was listed in the most recent Species List for the PN site in 2020 as a common native species (Beacon, 2020).

B.1.6 Riparian Birds

Birds are mobile receptors that will forage from a large home range. During breeding and rearing of young, the home range is often reduced.

B.1.6.1 Bufflehead

The Bufflehead (*Bucephala albeola*) is Canada's smallest diving duck. Males average 450 g in weight and females about 340 g. During migration they may carry up to an additional 115 g of fat. Their breeding habitat is small ponds, usually in wooded areas. They are not gregarious and typically occur in groups of 10 birds or fewer. Their summer breeding range is north and west of the Great Lakes. Their Canadian overwinter range includes the west coast and favoured spots around Lake Ontario and the southern coasts of New Brunswick and Nova Scotia. Buffleheads nest in tree cavities. The female lays a clutch of 7 to 11 eggs. Hatching occurs about 30 days later and ducklings remain in the nest only 24 to 36 hours before being lead to the nearest waterbody. The young may be eaten by pike or other predators. The Buffleheads' main foods are arthropods, mostly insect larvae in freshwater and small crustaceans, such as shrimps, crabs, amphipods, in salt water. In fall they eat many seeds of aquatic plants, and in winter they take small marine snails or freshwater clams in their respective habitats (EC & CWF, 2013).

Bufflehead was listed in the most recent Species List for the PN site in 2020 as a common species (Beacon, 2020).

B.1.6.2 Common Tern

The Common Tern (*Sterna hirundo*) has a circumpolar range and is strongly migratory. It winters in coastal tropical and subtropical areas and breeds in the northern part of its range. Adults have an average length of 31 to 38 cm and an average weight of 93 to 200 g. Common Terns arrive on northern breeding grounds from late April through mid-May (The Cornell Lab of Ornithology, n.d.(a)). They nest on any flat, poorly vegetated surface close to water. The female lays 1 to 4 eggs. The eggs hatch in around 21 or 22 days and the chicks fledge in 22 to 28 days. Like most terns, this species feeds by plunge-diving for fish. However, it is an opportunistic feeder and molluscs, crustaceans and other invertebrate prey may form a significant part of the diet in some areas (BTO, 2013).

Common Tern was listed in the most recent Species List for the PN site in 2020 as an uncommon, migratory species which breeds at the Site (Beacon, 2020).

B.1.6.3 Ring-Billed Gull

The Ring-billed Gull (*Larus delawarensis*) is a medium-sized gull, measuring 45 cm from bill to tail, having a 50-cm wingspan and weighing about 0.7 kg. The Ring-billed Gull is probably the most numerous gull in North America. Ring-billed Gulls nest in colonies of hundreds or thousands of pairs. A small percentage of Canadian Ring-billed Gulls winter on the Great Lakes, usually near open water on lakes Erie and Ontario and the Niagara River. Breeding colonies arrive in Eastern Canada in late February or early March. They lay a clutch of three eggs beginning in April in the Great Lakes area. Ring-billed Gulls incubate their eggs for approximately 25 to 27 days until they hatch. The young generally fledge five to six weeks later. The diet of Ring-billed Gulls is variable. These gulls are opportunistic feeders that readily switch from one type of food to another. During the spawning season they will feed primarily on smelt; after a rain they seek out earthworms; during farmers' ploughing and harvesting seasons they feed on insect larvae and mice. At other times of the year they will feed on carrion, flying insects, and the young of other birds, especially small ducklings (EC & CWF, 2013).

Ring-billed Gull was listed in the most recent Species List for the PN site in 2020 as an abundant species which are present year-round and breed at the Site (Beacon, 2020).

B.1.6.4 Trumpeter Swan

The Trumpeter Swan (*Cygnus buccinator*) is a large bird with white feathers and black legs and feet. Adult males weigh an average of 12 kg. The female is slightly smaller, averaging 10 kg. Trumpeter Swans are found in Canada year round. In winter they congregate in areas where water does not freeze and food is available. Breeding birds select nest sites that are surrounded by water from 10 cm to several metres in depth. They frequently construct their nests on old beaver houses and dams or emergent vegetation even before a site is completely free of ice. Most nests are used year after year, usually by the same pair. A female produces an average of 5 or 6 eggs which she incubates for about 32 days until they hatch. The cygnets grow from approximately 300 g at hatching to approximately 7 kg at fledging. During summer, trumpeters feed on leaves, tubers, and roots of aquatic plants at depths up to 1 m, which they reach by dipping their heads and necks, or by up-ending. The cygnets, or young, feed predominately on insects and other invertebrates for the first few weeks of life but may start feeding on plants before they are two weeks old (EC & CWF, 2013).

Trumpeter Swan was listed in the most recent Species List for the PN site in 2020 as an uncommon species which are present year-round and breed at the Site (Beacon, 2020).

B.1.7 Riparian Mammals

B.1.7.1 Muskrat

The Muskrat (*Ondatra zibethicus*) is a large rodent, measuring approximately 50 cm from tip of the nose to tail, and weighing on average 1 kg. Muskrats exist all over North America, from the Arctic Ocean in the north to the Gulf of Mexico in the south, from the Pacific Ocean in the west to the Atlantic Ocean in the east. Muskrats prefer freshwater marshes, marshy areas of lakes, and slow-moving streams. The preferred water depth in these areas is 1 to 2 m, deep enough not to freeze fully during the winter but shallow enough to allow aquatic vegetation to grow. Muskrats nest in compact mounds of partially dried and decayed plant material such as cattails bulrushes. In winter, Muskrats generally occupy lodges that they build through burrowing underneath their mounds (EC & CWF, 2013).

Muskrats mainly feed on aquatic plants such as cattails, bulrushes, horsetails, or pondweeds; however, they prefer cattails. When aquatic plants are unavailable, Muskrats are also known to feed on fish, frogs, and clams. Breeding generally occurs in March, April, or May. Birth of the litter usually occurs within 1 month of mating and usually contains 5 to 10 young. Breeding can occur multiple times throughout the season (EC & CWF, 2013).

Muskrat was listed in the most recent Species List for the PN site in 2020 as an uncommon species which are present year-round at the Site (Beacon, 2020).

B.2 Terrestrial Biota

B.2.1 Earthworms

Earthworms live in soil, and depending on the species they either move vertically or horizontally in different soil layers. Earthworms acquire their nutrition through the organic matter in soil as well as the decomposing remains of other animals. They can devour one third of their own body weight per day.

B.2.2 Terrestrial Plants

B.2.2.1 Chokecherry

Chokecherry (*Prunus virginiana ssp. virginiana*) is a small tree or shrub growing to approximately 8 m, and is native to North America (Ontario Trees & Shrubs, n.d.). Chokecherries are a food source for birds.

Chokecherry was listed in the most recent Species List for the PN site in 2020 as a common native species at the Site (Beacon, 2020).

B.2.2.2 Eastern Hemlock

Eastern Hemlock (*Tsuga canadensis*) is a coniferous tree, growing up to 30 m. It is native to eastern North America. In Canada, the Eastern Hemlock is found from New Brunswick and Nova Scotia to southern Quebec and Ontario (USDA, 2002a).

Eastern hemlock was listed in the most recent Species List for the PN site in 2020 as an uncommon native species at the Site (Beacon, 2020).

B.2.2.3 New England Aster

New England Aster (*Symphyotrichum novae-angliae* formerly *Aster novae-angliae*) is a flowering herbaceous perennial plant, growing up to approximately 2 m. It is native to the majority of North America east of the Rocky Mountains, with the exception of parts of the southern United States and far northern Canada (USDA, 2003).

New England Aster was listed in the most recent Species List for the PN site in 2020 as a common native species at the Site (Beacon, 2020).

B.2.2.4 Pines

Various pines have been observed during terrestrial inventories within the PN site. Several species are listed in the most recent Species List for the PN site in 2020 including Black Pine and

Scotch Pine, which are listed as common introduced species; and Eastern Red Pine, which is listed as an uncommon native species; and Red Pine, which is listed as rare (Beacon, 2020).

B.2.2.5 Red Ash

Red Ash (*Fraxinus pennsylvanica*) is a medium sized deciduous tree, growing up to 12 to 25 m tall and 60 cm diameter trunk. The Red Ash is native to eastern and central North America, and occurs throughout southern and eastern Ontario (Northern Ontario Plant Database, 2013).

Red Ash was listed in the most recent Species List for the PN site (under Green Ash) in 2020 as a common native species at the Site (Beacon, 2020).

B.2.2.6 Sandbar Willow

Sandbar Willow (*Salix exigua*) is a deciduous shrub, growing up to 4 to 7 m. The Sandbar Willow is native to North America, primarily in the west. Sandbar Willow provides wood and shelter for a number of birds (USDA, 2002b).

Sandbar Willow was listed in the most recent Species List for the PN site in 2020 as a common native species at the Site (Beacon, 2020).

B.2.3 Terrestrial Birds

B.2.3.1 Red-winged Blackbird

The Red-winged Blackbird (*Agelaius phoeniceus*) is one of the most abundant birds across North America. Adults are approximately 17 to 23 cm in length and weigh 32 to 77 g. Red-winged Blackbirds breed in wetlands across Canada from southern Yukon to south western Newfoundland and Labrador, spanning northern Saskatchewan, central Manitoba, north-central Ontario and southern Quebec. They winter in southern British Columbia, extreme southern Ontario, Nova Scotia and rarely in southern Quebec. Red-winged Blackbirds roost in flocks in all months of the year. In summer, small numbers roost in the wetlands where the birds breed. Winter flocks can be congregations of several million birds, including other blackbird species and starlings. Each morning, the roosts spread out, traveling as far as 50 miles to feed, then re-forming at night. Red-winged Blackbirds build their nests low among vertical shoots of marsh vegetation, shrubs, or trees. Females lay a clutch of 2 to 4 eggs. The eggs hatch within 11 to 13 days, and the young fledge approximately 11 to 14 days later. Red-winged Blackbirds eat mainly insects in the summer and seeds, including corn and wheat, in the winter. Sometimes they feed by probing at the bases of aquatic plants with their bills, prying them open to get at insects hidden inside. In fall and winter, they eat weedy seeds such as ragweed and cocklebur as well as native sunflowers and waste grains (EC & CWF, 2013).

Red-winged Blackbird was listed in the most recent Species List for the PN site in 2020 as a migratory, breeding species. It is abundant at the Site (Beacon, 2020).

B.2.3.2 Red-tailed Hawk

The Red-tailed Hawk (*Buteo jamaicensis*) is likely the most common hawk in North America. Adult males average 45 to 56 cm in length and weigh and average of 690 to 1300 g. Adult females are somewhat larger, averaging 50 to 65 cm in length and weighing 900 to 1460 g.

Red-tailed Hawks occupy just about every type of open habitat on the continent. They typically put their nests in the crowns of tall trees, cliff ledge or on artificial structures such as window ledges and billboard platforms. Females typically lay 1 to 5 eggs. The eggs are incubated for about 28 to 35 days and the young fledge in about 42 to 46 days. Mammals make up the bulk of most Red-tailed Hawk meals. They prey upon voles, mice, wood rats, rabbits, snowshoe hares, jackrabbits, and ground squirrels. The hawks also eat birds, snakes and carrion. Individual prey items can weigh anywhere from less than an ounce to more than 5 pounds (The Cornell Lab of Ornithology, n.d.(b)).

Red-tailed Hawk was listed in the most recent Species List for the PN site in 2020 as a migratory, breeding species. It is common at the Site (Beacon, 2020).

B.2.4 Terrestrial Mammals

B.2.4.1 Meadow Vole

The Meadow Vole (*Microtus pennsylvanicus*) is a small herbivorous rodent, measuring 8.9 to 13 cm from head to tail, and weighing between 0.02 to 0.04 kg. The Meadow Vole is found across Canada, Alaska and the northern United States. They can be found mainly in meadows, lowland fields, grassy marshes, and along rivers and lakes. They are also occasionally found in flooded marshes, high grasslands near water, and orchards or open woodland if grassy (US EPA, 1993).

The Meadow Vole breeds throughout the year, but breeding peaks from April to October. Gestation lasts approximately 21 days, with litter sizes ranging from 1 to 9 (NatureServe, 2012). Meadow voles mainly feed on shoots, grass, and bark. Voles are prey for hawks and owls as well as several mammalian predators such as short-tailed shrews, badgers, and foxes (US EPA, 1993).

Meadow Vole was listed in the most recent Species List for the PN site in 2020 as a common species that is present at the Site year-round. (Beacon, 2020).

B.2.4.2 Red Fox

The Red Fox (*Vulpes vulpes*) is a small mammal, ranges in length between 90 to 112 cm, and weighs approximately 4.54 kg (US EPA, 1993). Red Foxes are found throughout Canada in all provinces and territories. They generally occupy a home range between 4 to 8 km^2 and reside in a main underground den and one or more other burrows within their home range. The tunnels are up to 10 m long and lead to a chamber 1 to 3 m below surface. Foxes breed between late December and mid-March, and pups are born from March through May, with litter sizes ranging from 1 to 10. Pup-rearing is the primary focus of the Red Fox during spring and early summer. Their diet is predominantly small mammals such as mice and voles, but they also eat insects, fruits, berries, seeds and nuts. Their diet varies with the seasons, eating mainly small mammals in fall and winter, nesting waterfowl in the spring, and insects and berries in the summer (EC & CWF, 2013).

Red Fox was listed in the most recent Species List for the PN site in 2020 as an uncommon species that has breeding habitat and is present at the Site year-round. (Beacon, 2020).

B.2.4.3 White-Tailed Deer

The White-tailed Deer (*Odocoileus virginianus*) is the smallest of the native Canadian deer, measuring 151 to 240 cm in total length, and weighing between 50 to 135 kg (adult). Males are typically 20 to 55% larger than females (Naughton, 2012). The White-tailed Deer is widespread throughout North America, preferring open forests intermixed with "*meadows, clearings, grasslands, and riparian flatlands*". The White-tailed Deer home range size ranges between 60 to 500 hectares (Naughton, 2012).

The White-tailed Deer diet consists mainly of terrestrial vegetation such as fresh grasses, forbs, fruits, nuts, browse, as well as mushrooms. In areas near the Great Lakes, White-tailed Deer are known to consume alewives that have washed ashore after spawning. Predators of the white-tail deer include wolves, coyotes, cougars, and black bears (Naughton, 2012).

If a female White-tailed Deer is well nourished, it breeds yearly. Mating season for Canadian deer typically take place between late October and mid-December, with a breeding peak in mid-November. Gestation lasts approximately 200 days with first time mothers typically producing one off-spring and repeat, larger, well-nourished mothers producing two or three off-springs. Fawns are fully weaned by four months (Naughton, 2012).

White-Tailed Deer was listed in the most recent Species List for the PN site in 2020 as an uncommon species that has breeding habitat and is present at the Site year-round. (Beacon, 2020).

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Appendix C Limiting Gross Beta/Gamma Radionuclides for Ecological Receptors

C.1 Background

Beta and gamma emissions from PN are measured as a gross value, rather than by individual radionuclide. In 2003, a study by the Candu Owners Group (COG, 2003) sought to characterize the effluent from the nuclear power stations. However, it is difficult to assign percentages of gross beta/gamma effluent to individual radionuclides using the information available. Without a thorough understanding of the proportions of radionuclides in composition of the gross beta gamma emissions, it is conservative to choose one radionuclide to be representative of the gross value. In addition, it would be impractical to assess a long list of radionuclides when one can be chosen to conservatively represent their effects.

Updated Derived Release Limits (DRL) for the Pickering Nuclear Generating Station were developed in 2016 (OPG, 2016). The DRL for a given radionuclide is the release rate to air or surface water during normal operation of a nuclear facility that could cause an individual of the most highly exposed receptor group around PN to receive and be committed to a dose equal to the annual regulatory dose limit over a calendar year (OPG, 2016). There are six potential critical groups considered in the DRL report, representing persons likely to receive the highest exposures for different radionuclides via releases to air or to water.

With respect to the selection of radionuclides to represent total particulate in air and gross beta-gamma activity in water, a process of selection is undertaken according to the COG DRL Guidance (COG, 2013). The limiting radionuclide for air was identified to be cobalt-60, based on dose to an Urban Resident / infant. The limiting radionuclide for water was identified to be cesium-134, based on dose to an adult Sport Fisher. Cesium-134 was included in the selection process based on detections in effluent, in accordance with DRL guidance (COG, 2013).

For the 2017 ERA, DRLs were calculated for ecological receptors to identify the limiting radionuclide to represent gross beta-gamma (Appendix C of Ecometrix and Golder, 2018). The radionuclides considered in the determination of the DRLs for gross beta-gamma in water were taken from OPG (2011a, 2011b). The list was as follows: P-32, S-35, Sc-46, Cr-51, Mn-54, Fe-55, Fe-59, Co-60, Sr-90 (Y-90), Zr-95, Nb-95, Ru-106, Sn-113, Sb-124, Sb-125, I-131, Cs-137, Eu-154, Gd-153, Tb-160, Zn-65. The representative radionuclide identified as a result of the assessment was cobalt-60.

The purpose of this Appendix is to document the process undertaken to determine whether cesium-134 should also be considered in the selection, and whether it is the limiting radionuclide to represent gross beta-gamma activity in water, or if cobalt-60 should continue to be used for the ecological risk assessment.

C.2 Methodology

An IMPACT DRL Version 5.5.2 was used to calculate doses to ecological receptors for the EcoRA. Model setup was completed consistent with the ecological exposure pathways described in Section 4.1.4 and the exposure factors described in Section 4.2.3.4 of the main report. The model was set up such that receptors are exposed to equal concentrations of cobalt-60, cesium-134 and cesium-137 at the outfall and at Frenchman's Bay.

The CSA N288.1 Aquatic Dispersion Model is used in the IMPACT model (described in Section 9.2.1 of the 2016 DRL Report, OPG 2016) was used to estimate exposure concentrations of lake water at the outfall and at Frenchman's Bay, at the locations of VECs selected for the 2021 EcoRA. The parameter values used in the dispersion model are listed in Table C-1 below.

Table C-1: Parameter Values for CSA Model and Resulting Dilution Factors

Parameter	Units	Description	Frenchman's Bay	Outfall	Source
X	m	distance from PN	1,130	0	Assumption/measured via Google Earth
β	na	recirculation factor	2	2	OPG, 2016
Q_V (1)	L/s	discharge flow	1.43E+05	1.43E+05	OPG, 2016
κ	na	proportionality factor	3.39E-07	3.39E-07	OPG, 2016
D_0	na	initial dilution factor	1	1	OPG, 2016
U_C	m/s	current speed to the right	0.252	0.252	Section 2.3.4.1 (main report)
U_C	m/s	current speed to the left	0.185	0.185	Section 2.3.4.1 (main report)
α	na	fraction of year current flows toward receptor	1.0	1.0	OPG, 2016
d	m	average plume depth	6	10	OPG, 2016

Doses to ecological receptors with water / sediment exposure pathways were examined and compared for relative dose contributions from the dictated concentrations of cobalt-60, cesium-134 and cesium-137 of 1 Bq/L each.

C.3 Results

Table C-2 and C-3 present the dose and percentage of dose received from each of cobalt-60, cesium-134 and cesium-137. Figure C-1 provides a graphical comparison of the relative dose to each ecological receptor.

Table C-2: Dose to Ecological Receptors from 1 Bq/L of Cobalt-60, Cesium-134 and Cesium-137 in Waterborne Discharge

VEC	Outfall				PN site				
	Benthic Inver.	Lake Trout	Ring-Billed Gull (Outfall)	White Sucker	Meadow Vole	Red Fox	Red-Tailed Hawk	Red-Winged Blackbird	White-Tailed Deer
Co-60	2.89E-01	3.06E-04	7.83E-02	6.70E-02	1.24E-08	2.59E-08	5.96E-07	6.55E-07	1.99E-07
Cs-134	4.21E-02	1.72E-02	2.52E-02	2.62E-02	6.52E-07	1.44E-06	2.32E-06	1.69E-06	7.63E-06
Cs-137	1.71E-02	1.54E-02	1.58E-02	1.86E-02	6.52E-07	1.44E-06	1.97E-06	1.44E-06	4.17E-06

VEC	Frenchman's Bay					
	Bufflehead	Common Tern	Lake Trout	Ring-Billed Gull	Trumpeter Swan	White Sucker
Co-60	8.12E-02	7.81E-02	3.06E-04	7.87E-02	7.98E-02	6.70E-02
Cs-134	1.41E-02	3.34E-02	1.72E-02	2.53E-02	1.30E-02	2.62E-02
Cs-137	6.38E-03	2.28E-02	1.54E-02	1.59E-02	5.49E-03	1.86E-02

Table C-3: Percentage of Combined Dose Attributed to Cobalt-60, Cesium-134 and Cesium-137 in Waterborne Discharge

VEC	Outfall				PN site				
	Benthic Inver.	Lake Trout	Ring-Billed Gull (Outfall)	White Sucker	Meadow Vole	Red Fox	Red-Tailed Hawk	Red-Winged Blackbird	White-Tailed Deer
Co-60	83%	1%	66%	60%	1%	1%	12%	17%	2%
Cs-134	12%	52%	21%	23%	50%	50%	47%	45%	64%
Cs-137	5%	47%	13%	17%	50%	50%	40%	38%	35%

VEC	Frenchman's Bay					
	Bufflehead	Common Tern	Lake Trout	Ring-Billed Gull	Trumpeter Swan	White Sucker
Co-60	80%	58%	1%	66%	81%	60%
Cs-134	14%	25%	52%	21%	13%	23%
Cs-137	6%	17%	47%	13%	6%	17%

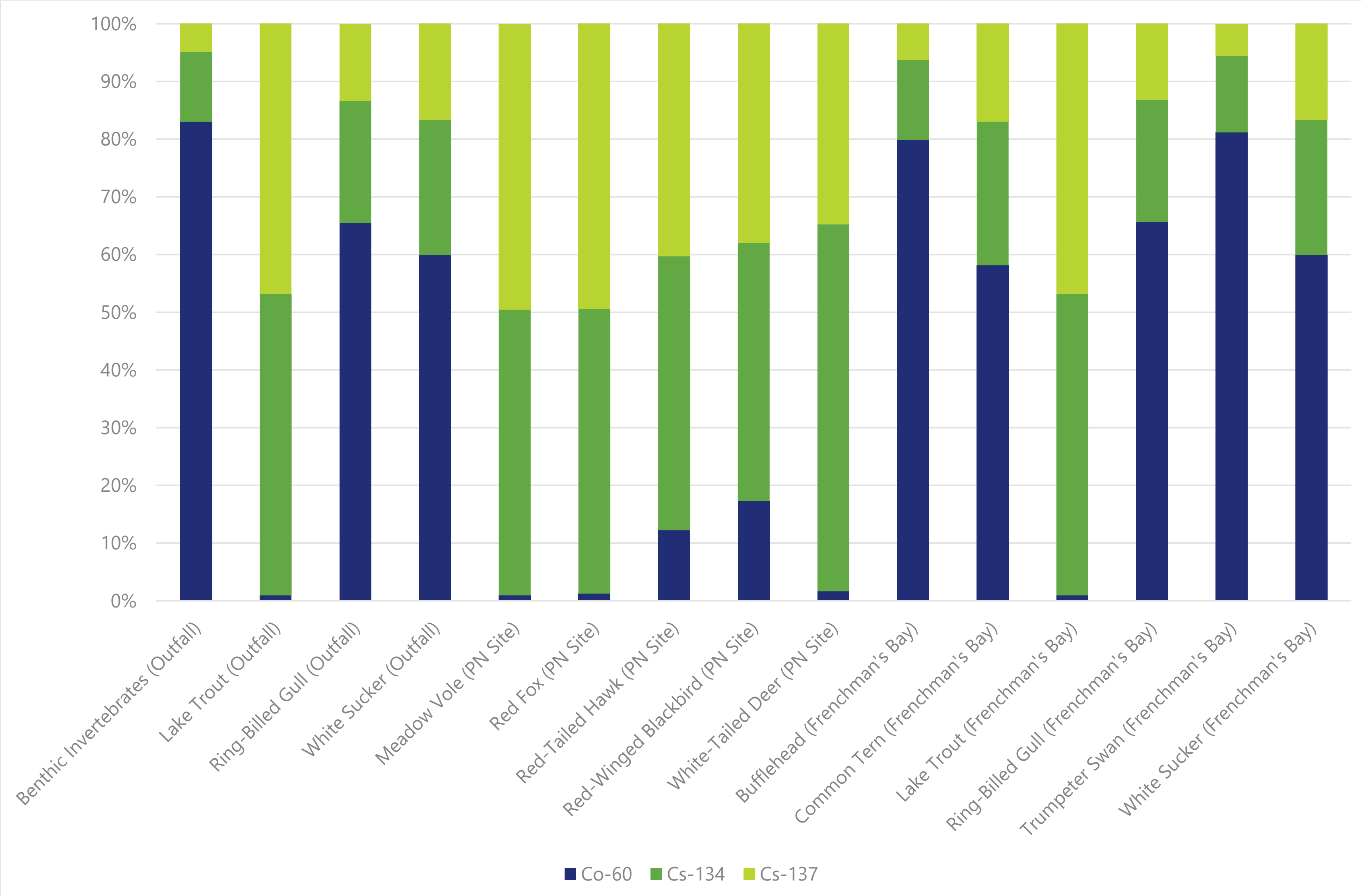

Figure C-1: Relative Contribution to Dose

C.4 Discussion

The results of the analysis show that the limiting radionuclide for receptors that have sediment exposures (i.e., benthic invertebrates, riparian birds, and white sucker) is cobalt-60. Receptors with sediment exposures will be exposed to relatively higher sediment concentrations of cobalt-60, since it has a higher sediment distribution coefficient (4.0E4 L/kg dw) relative to cesium-134 or cesium-137 (9.5E3 L/kg) (IAEA 2010).

For the remaining terrestrial receptors at the PN site and pelagic fish (i.e. lake trout), that do not have exposures to sediment, the limiting radionuclide is cesium-134. As shown on Table C-3, the selection of cesium-134 as the limiting radionuclide is appropriate for all receptors with exposure pathways to lake water. The selection of cesium-134 is expected to be a conservative surrogate for all beta-gamma exposures for ecological receptors.

There is potential for an under-estimation of radiological dose for benthic invertebrates, riparian birds, and benthic fish (e.g. white sucker) through the use of cesium-134 as the limiting radionuclide. This may be considered as an uncertainty for any ecological receptors with sediment exposures and results should be interpreted accordingly.

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Appendix D Sample Calculations

Table D.1: Sample Calculation - Urban Resident (Adult) Drinking Water Exposure and Risk to Hydrazine with Decay (t½ =1.3 days)

Parameter	Symbol	Equation	Hydrazine		
			Value	Unit	Source
Environmental Media Concentration					
Water Concentration	C_w	-	2.50E-04	mg/L	Maximum from Lake Water, Table 3.23
Dilution Factor (Outfall)	$DF_{outfall}$	-	42	unitless	Section 3.2.6.2.2
Dilution Factor (Ajax WSP)	$DF_{Ajax\ WSP}$	-	41.5	unitless	Section 3.2.6.2.2
Half-life hydrazine	t½	-	1.3	days	Section 3.2.6.2.2
Hydrazine Decay Constant	λ	λ = ln(2)/t½	0.53	unitless	Calculation
Distance to Ajax WSP	d	-	6500	m	Table 2.18
Current Velocity to the West	v	-	0.185	m/s	Section 2.3.4.1
Travel Time	t	t = d/v/(60sec*60min*24hr)	0.41	days	Calculation
Hydrazine Decayed Concentration t½ =1.3 days	$C_{hydrazine\ (t½\ =1.3)}$	$C_{hydrazine\ (t½\ =1.3)}$ = C_w * EXP(-λt)	2.01E-04	mg/L	Calculation
Estimated concentration in Lake Ontario at Ajax WSP (mg/L)	C_{WSP}	C_{WSP} = $C_{hydrazine\ (t½\ =1.3)}$ / $DF_{Ajax\ WSP}$	4.86E-06	mg/L	Calculation
Degradation factor during water treatment	df	-	0.1	unitless	Section 3.2.6.2.2
Estimated drinking water concentration after treatment at Ajax WSP (mg/L)	C_{dw}	C_{dw} = C_{WSP} * df	4.86E-07	mg/L	Calculation
Human Exposure Factors (Adult)					
Drinking Water Intake	DWIR	-	1.5	L/d	Table 3.17
Days per Week/7 (D2)	D2	-	1	d/d	Table 3.17
Weeks per Year/52 (D3)	D3	-	1	wk/wk	Table 3.17
Years Exposed (D4)	D4	-	80	years	Table 3.17
Fraction of Water Obtained from WSP	f_0	-	1	unitless	Assumption
Body Weight	BW	-	70.7	kg	Table 3.17
Life Expectancy	LE	-	80	years	Table 3.17
Relative Absorption factor from the GI tract for contaminant i	RAF_{GITi}	-	1	unitless	Table 3.17
TRV (Oral Slope Factor)	TRV	-	3	$(mg/kg\ d)^{-1}$	Table 3.29
Human Dose and ILCR					
Ingestion Dose	Dose	Dose = (C_{WSP} * DWIR * D2 * D3 * D4 * f_0 * RAF_{GITi})/(BW*LE)	1.03E-08	mg/kg d	Calculation
Incremental Lifetime Cancer Risk	ILCR	ILCR = Oral Slope Factor * Dose	3.09E-08	unitless	Calculation

Table D.2: Sample Calculation-Sport Fisher Exposure and Risk to Hydrazine

Parameter	Symbol	Calculation	Hydrazine		
			Value	Unit	Source
Environmental Media Concentration					
Water Concentration	C_w	-	2.50E-04	mg/L	Maximum from Lake Water, Table 3.23
Fish Concentration					
Bioaccumulation Factor	BAF_{fish}	-	3.16	L/kg fw	Table 3.26
Tissue Concentration	C_{fish}	$C_{fish} = C_w * BAF_{fish}$	7.90E-04	mg/kg fw	Calculation (Section 4.2.3.3)
Human Exposure Factors (Adult)					
Fish Ingestion	IR_{fish}	-	0.111	kg/d	Table 3.17
Years Exposed (D4)	D4	-	35	a	Table 3.17
Days in which consumption occurs	Di	-	365	d/a	Table 3.17
Body Weight	BW	-	70.7	kg	Table 3.17
Life Expectancy	LE	-	80	years	Table 3.17
Relative Absorption factor from the GI tract for contaminant i	RAF_{GITi}	-	1	unitless	Table 3.17
TRV (Oral Slope Factor)	TRV	-	3	$(mg/kg\ d)^{-1}$	Table 3.29
Human Dose and ILCR					
Ingestion Dose	Dose	$Dose = (C_{fish} * IR_{fish} * Di * RAF_{GITi} * D4)/(BW * 365\ d/a * LE)$	5.43E-07	mg/kg d	Calculation (Section 3.2.3.2)
Incremental Lifetime Cancer Risk	ILCR	ILCR = Oral Slope Factor * Dose	1.63E-06	unitless	Calculation (Section 3.4.1)

Table D.3: Sample Calculation -Trumpeter Swan (at Frenchman's Bay) Dose and Risk Calculations for Copper

Parameter	Symbol	Calculation	Copper		
			Value	Unit	Source
Environmental Media Concentration					
Water Concentration	C_w	-	2.10E-03	mg/L	Maximum surface water concentration at Frenchman's Bay, Table 4.30
Sediment Concentration (dry weight)	$C_{s(dw)}$	-	7.40E+01	mg/kg dw	Maximum sediment concentration at Frenchman's Bay, Table 4.30
Aquatic Plant Concentration					
Bioaccumulation Factor (BAF)	$BAF_{aquatic\ plant}$	-	3.00E+03	L/kg fw	Table 4.19
Tissue Concentration	$C_{aquatic\ plant}$	$C_{aquatic\ plant} = C_w * BAF_{aquatic\ plant}$	6.30E+00	mg/kg fw	Calculation (Section 4.2.3.3)
Trumpeter Swan Exposure Factors					
Water Intake	IR_w	-	2.94E-01	kg/d	Table 4.17
Sediment Intake	IR_s	-	1.14E-02	kg dw/d	Table 4.17
Aquatic Plant Intake	$IR_{aquatic\ plant}$	-	1.39E+00	kg/d fw	Table 4.17
Body Weight	BW	-	11	kg	Table 4.17
Toxicological Benchmark	TRV	-	6.17E+01	mg/kg d	Table 4.39
Trumpeter Swan Dose and HQ					
Ingestion Dose	D_{ing}	$D_{ing} = (C_w*IR_w + C_{s(dw)}*IR_s+C_{aquatic\ plant}*IR_{aquatic\ plant})/BW$	8.71E-01	mg/kg d	Calculation (Section 4.2.3.2) and Table 4.32
Hazard Quotient	HQ	$HQ = D_{ing}/TRV$	1.41E-02	unitless	Calculation (Section 4.4.1) and Table 4.42

Table D.4: Sample Calculation - Bufflehead at Frenchman's Bay - Radiological Dose for Cobalt-60

Parameter	Symbol	Calculation	Cobalt-60		
			Value	Unit	Source
Environmental Media Concentrations					
Water Concentration (Co-60)	C_w	-	<0.10	Bq/L	Maximum surface water concentration, Table 4.28
Sediment Concentration (dry weight)	$C_{s(dw)}$	-	<6.0	Bq/kg dw	Maximum sediment concentration, Table 4.28
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)	$C_{s(dw)}'$	$C_{s(dw)}' = C_{s(dw)} * \rho_s * d * 1000\ L/m^3$	1.20E+02	Bq dw/ m^2	Calculated
Aquatic Plant Concentration					
Bioaccumulation Factor - Aquatic Plant	$BAF_{aquatic\ plant}$	-	7.90E+02	L/kg fw	Table 4.19
Aquatic Plant Concentration (fresh weight)	$C_{aquatic\ plant}$	$C_{aquatic\ plant} = C_w * BAF_{aquatic\ plant}$	7.90E+01	Bq/kg fw	Calculation (Section 4.2.3.3)
Benthic Invertebrate Concentration					
Bioaccumulation Factor - Benthic Invertebrates	$BAF_{benthic\ inv}$	-	1.10E+02	L/kg fw	Table 4.19
Benthic Invertebrate Tissue Concentration	$C_{benthic\ inv}$	$C_{benthic\ inv} = C_w * BAF_{benthic\ inv}$	1.10E+01	Bq/kg fw	Calculation (Section 4.2.3.3)
Bufflehead Exposure Factors					
Intake Rate, Water	IR_w	-	3.60E-02	L/d	Table 4.17
Intake Rate, Sediment	IR_s	-	4.65E-03	kg dw/d	Table 4.17
Intake Rate, Aquatic Plant	$IR_{aquatic\ plant}$	-	1.80E-02	kg/d fw	Table 4.17
Intake Rate, Benthic Invertebrate	$IR_{benthic\ inv}$	-	1.61E-01	kg/d fw	Table 4.17
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 4.21
Bufflehead Tissue Concentration	C_t	$C_t = f_0 * TF_{ing} * (C_w*IR_w + C_{s(dw)} * IR_s + C_{aquatic\ plant} * IR_{aquatic\ plant} + C_{benthic\ inv} * IR_{benthic\ inv})$	9.22E+00	Bq/kg fw	Calculated (Section 4.2.3.3)
Dose Conversion Factor (Internal) - Duck	DC_{int}	-	2.38E-04	(µGy/hr)/(Bq/kg fw)	Table 4.23
Internal Dose	D_{int}	$D_{int} = C_t * DC_{int}$	2.19E-03	µGy/hr	Calculated (Section 4.2.3.1)
Internal Dose (converted units)	D_{int}'	$D_{int}' = D_{int} * 24\ h/d / 1000\ µGy/mGy$	5.26E-05	mGy/d	Calculated
Bufflehead External Dose (Radiological)					
Occupancy Factor, Sediment - Riparian Birds	OF_s	-	0	unitless	Table 4.18
Occupancy Factor, Sediment Surface - Riparian Birds	OF_{ss}	-	0.5	unitless	Table 4.18
Dose Conversion Factor (External, on soil) - Duck	$DC_{ext\ (on\ soil)}$	-	7.50E-06	(µGy/hr)/(Bq/m^2)	Table 4.23
External Dose	D_{ext}	$D_{ext} = f_0 * (C_{s(dw)}' * OF_{ss} * DC_{ext\ (on\ soil)})$	4.50E-04	µGy/hr	Calculated (Section 4.2.3.1)
External Dose (converted units)	D_{ext}'	$D_{ext}' = D_{ext} * 24\ h/d / 1000\ µGy/mGy$	1.08E-05	mGy/d	Calculated
Bufflehead Total Dose (radiological)					
Total Dose	D_{total}	$D_{total} = D_{int} + D_{ext}$	2.64E-03	µGy/hr	Calculated
Total Dose (converted units)	D_{total}'	$D_{total}' = D_{int}' + D_{ext}'$	6.34E-05	mGy/d	Calculated

Table D.5: Sample Calculation - Meadow Vole (at PN Site) Dose and Risk Calculations for Copper

Parameter	Symbol	Calculation	Copper		
			Value	Unit	Source
Environmental Media Concentration					
Water Concentration	C_w	-	2.00E-03	mg/L	Maximum at PN site, Table 4.30
Soil Concentration	$C_{s(dw)}$	-	8.30E+02	mg/kg dw	Maximum at PN site, Table 4.30
Terrestrial Plant Concentration					
Bioaccumulation Factor (BAF)	BAF_{plant}	-	8.00E-01	kg dw/kg dw	Table 4.20
Dry to fresh weight ratio	moisture	-	2.00E-01	dw/fw	Table 4.20
Bioaccumulation Factor (BAF)	BAF_{plant}'	$BAF_{plant}' = BAF_{plant} * moisture$	1.60E-01	kg dw/kg fw	Calculation
Tissue Concentration	C_{plant}	$C_{plant} = C_{s(dw)} * BAF_{plant}'$	1.33E+02	mg/kg fw	Calculation
Vole Exposure Factors					
Water Intake	IR_w	-	4.70E-03	kg/d	Table 4.17
Soil Intake	IR_s	-	5.28E-05	kg dw/d	Table 4.17
Terrestrial Plant Intake	IR_{plant}	-	1.10E-02	kg/d fw	Table 4.17
Body Weight	BW	-	0.0338	kg	Table 4.17
Toxicological Benchmark	TRV	-	1.51E+01	mg/kg d	Table 4.38
Vole Dose and HQ					
Ingestion Dose	D_{ing}	$D_{ing} = (C_w*IR_w + C_{s(dw)}*IR_s+C_{plant}*IR_{plant})/BW$	4.45E+01	mg/kg d	Calculation
Hazard Quotient	HQ	$HQ = D_{ing}/TRV$	2.9	unitless	Calculation

Table D.6: Sample Calculation - Meadow Vole (at PN Site) - Radiological Dose for Cesium-134

Parameter	Symbol	Calculation	Cesium-134		
			Value	Unit	Source
Environmental Media Concentrations					
Water Concentration (Outfall)	C_w	-	9.06E-01	Bq/L	Maximum surface water, Table 4.28
Soil Concentration	$C_{s(dw)}$	-	<1	Bq/kg dw	Maximum soil, Table 4.28
Soil density (loam)	ρ_s	-	1.30E+03	kg/m^3	CSA N288.1-20 cl. 6.3.2.2
Soil mixing depth	d	-	2.00E-01	m	Assumption
Soil Surface Concentration	$C_{s(dw)}'$	$C_{s(dw)}' = C_{s(dw)} * \rho_s * d$	260	Bq dw/m^2	Calculated
Terrestrial Plant Concentration					
Bioaccumulation Factor (BAF)	BAF_{plant}	-	5.30E-02	kg-dw soil /kg-dw biota	Table 4.20, CSA N288.1-20
Tissue Concentration	C_{plant}	$C_{plant} = C_{s(dw)} * BAF_{plant}$	5.30E-02	Bq/kg dw	Table 4.29
Vole Exposure Factors					
Intake Rate, Water	IR_w	-	4.70E-03	L/d	Table 4.17
Intake Rate, Soil	IR_s	-	5.28E-05	kg dw/d	Table 4.17
Intake Rate, Grass (dry weight)	IR_{plant}	-	2.20E-03	kg dw/d	Table 4.17
Fraction of Time Spent on Site	f_0	-	1.00E+00	unitless	
Vole Internal Dose (Radiological)					
Transfer Factor Ingestion - Vole	TF_{ing}		3.38E+01	d/kg fw	Table 4.22
Vole Tissue Concentration	C_t	$C_t = f_0 * TF_{ing} * (C_w * IR_w + C_{s(dw)} * IR_s + C_{plant} * IR_{plant})$	1.50E-01	Bq/kg fw	Calculated (Section 4.2.3.3)
Dose Conversion Factor (Internal)	DC_{int}	-	1.708E-04	(µGy/hr)/(Bq/kg fw)	Table 4.23
Internal Dose	D_{int}	$D_{int} = C_t * DC_{int}$	2.56E-05	µGy/hr	Calculated
Internal Dose (converted units)	D_{int}'	$D_{int}' = D_{int}$ * 24 h/d / 1000 µGy/mGy	6.14E-07	mGy/d	Calculated
Vole External Dose (Radiological)					
Occupancy Factor, Soil - Vole	OF_s	-	0	unitless	Table 4.18
Occupancy Factor, Soil Surface - Vole	OF_{ss}	-	1	unitless	Table 4.18
Dose Conversion Factor (External, in soil)	$DC_{ext\ (in\ soil)}$		7.92E-04	(µGy/hr)/(Bq/kg)	Table 4.23
Dose Conversion Factor (External, on soil)	$DC_{ext\ (on\ soil)}$		5.00E-06	(µGy/hr)/(Bq/m^2)	Table 4.23
External Dose	D_{ext}	$D_{ext} = f_0 * (C_{s(dw)}' * OF_{ss} * DC_{ext\ (on\ soil)})$	1.30E-03	µGy/hr	Calculated
External Dose (converted units)	D_{ext}'	$D_{ext}' = D_{ext}$ * 24 h/d / 1000 µGy/mGy	3.12E-05	mGy/d	Calculated
Vole Total Dose (radiological)					
Total Dose	D_{total}	$D_{total} = D_{int} + D_{ext}$	1.33E-03	µGy/hr	Calculated
Total Dose (converted units)	D_{total}'	$D_{total}' = D_{int}' + D_{ext}'$	3.18E-05	mGy/d	Calculated

Appendix E Assessment of Station Contribution to Observed Concentrations at Frenchman's Bay

E.1 Introduction and Conceptual Model

Frenchman's Bay, a provincially significant wetland, is designated an Environmentally Sensitive Area by the TRCA, and is an Aquatic Biology Core Area. Frenchman's Bay is a habitat for wetland vegetation, mainly cattails, benthic invertebrates, fish, and wildlife. The wetland is located in the northern section of the bay.

Surface water and sediment samples were collected in July 2015 from two general areas in Frenchman's Bay, the north end and the south end. In each area of Frenchman's Bay, 10 sediment samples and 3 surface water samples were collected. Water samples were analyzed for alkalinity, ammonia (total and un-ionized), BOD, COD, hardness, pH, conductivity, temperature, TSS, TRC (in-situ), petroleum hydrocarbons (PHC F1 to F4), morpholine, metals, TOC, and radionuclides. Sediment samples were analyzed for particle size, TOC, metals, and radionuclides. Details of the sampling program and results are provided in the main ERA report.

A screening against relevant water and sediment quality guidelines was conducted and the results are discussed in Section 4.1.3.2.4 of the main ERA report, and presented in the Tables A.9 and A.10 in Appendix A. A summary of the COPCs that exceeded water and sediment quality guidelines is provided in Table E.1. The exposure assessment, effects assessment and risk characterization are discussed for all parameters presented in Table E.1. The assessment at Frenchman's Bay presented in the main ERA report focused on parameters identified as COPCs in lake water samples and Frenchman's Bay water samples only; however, Appendix E provides a full assessment of all COPCs that exceeded water and sediment quality guidelines.

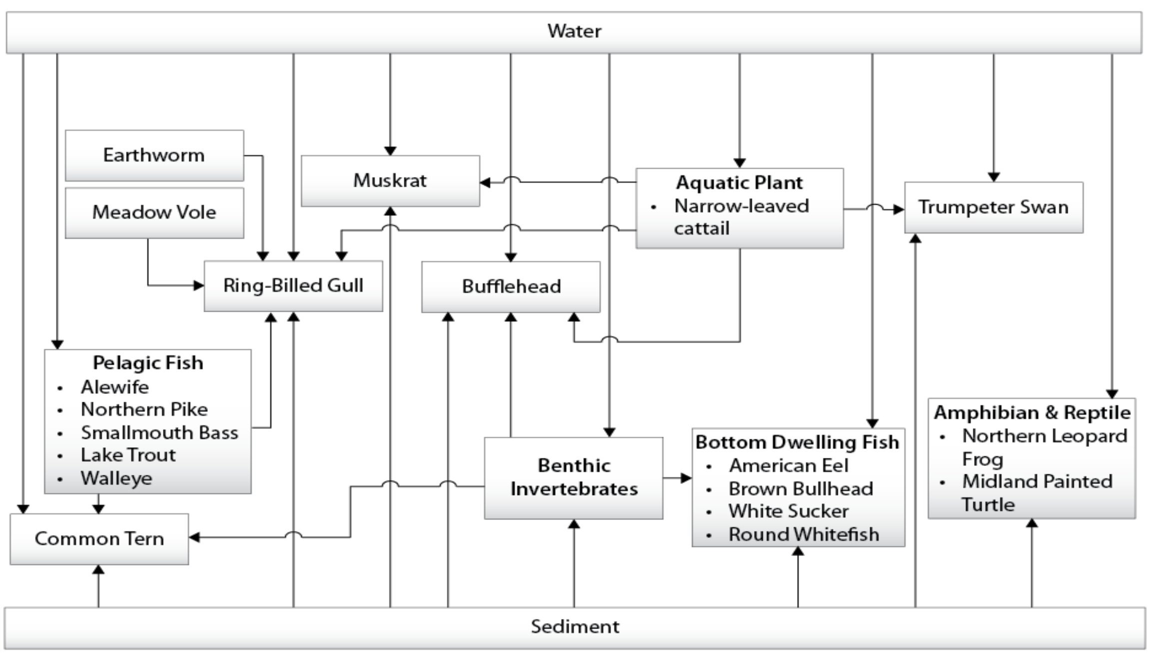
The TOC concentration in sediment exceeds the MECP guideline. However, it is expected that TOC in wetland locations will frequently exceed the MECP guideline, since the guideline for TOC is based on a Great Lakes data set, and no wetland guidelines are available. The screening level concentration (SLC) method used by the MECP is constrained by the range of values in the data set; it cannot yield a higher guideline. Therefore, the TOC guideline is not suitable for wetlands. TOC is not considered a COPC and is not discussed further.

Table E.1: Summary of 2015 Water and Sediment COPCs Exceeding Water Quality Guidelines

Water COPC	Sediment COPC
Total Aluminum Copper** Iron Sodium	Aluminum** Bismuth* Boron* Cadmium Calcium* Chromium Copper Iron Lead Manganese Nickel Phosphorus Thallium* Tin* Zinc

Note:
* Indicates the parameter exceeds a background concentration. No guideline exists.
** Did not exceed based on available screening criteria. Included as it was part of the 2017 ERA.

The ecological conceptual model for the aquatic environment at Frenchman's Bay is consistent with that presented in the main ERA report and shown in Figure E.1 below.



Note:
Riparian birds and mammals (i.e., Muskrat) are exposed by air immersion which is not shown in the figure.
Alewife was a VEC in the 2017 ERA and has been replaced by Emerald Shiner, also a pelagic fish.

Figure E.1: Conceptual Model for the Aquatic Environment

E.2 Exposure Assessment

The exposure assessment for Frenchman's Bay followed the methods described in the exposure assessment in Section 4.2 of the

The exposure concentrations in Table E.2, along with the exposure factors in Section 4.2.3.4, were applied to the equations in Section 4.2.3 in the main ERA report main ERA report. The exposure point concentrations for receptors at Frenchman's Bay are presented in Table E.2. The concentrations reflect maximum and UCLM sediment and water concentrations. The north and south end of the Bay have been assessed together, as there is not much variability in measurements to estimate the dose to birds and mammals (Table E.3).

Table E.2: Exposure Concentrations for Frenchman's Bay Exposure Assessment

Media	VEC Category	COPC	Units	Maximum Concentration	UCLM Concentration
Water	Aquatic invertebrate Fish Riparian birds Amphibians Riparian mammals Aquatic plants	Aluminum	mg/L	2.70E-01	2.03E-01
		Bismuth		<1.00E-03	<1.00E-03
		Boron		4.20E-02	3.86E-02
		Cadmium		1.00E-05	<1.00E-05
		Calcium		6.40E+01	5.77E+01
		Chromium		<5.00E-03	<5.00E-03
		Copper		2.10E-03	1.89E-03
		Iron		5.60E-01	4.27E-01
		Lead		9.20E-04	7.47E-04
		Manganese		8.00E-02	6.61E-02
		Nickel		1.30E-03	<1.13E-03
		Sodium		9.10E+01	7.57E+01
		Thallium		<5.00E-05	<5.00E-05
		Tin		<1.00E-03	<1.00E-03
		Zinc		7.40E-03	<6.02E-03
Sediment	Aquatic invertebrate Riparian birds Amphibians Riparian mammals Aquatic plants	Aluminum	mg/kg dw	1.30E+04	9.85E+03
		Bismuth		<1.00E+00	<1.00E+00
		Boron		2.50E+01	1.05E+01
		Cadmium		7.50E-01	5.37E-01
		Calcium		1.30E+05	9.72E+04
		Chromium		3.10E+01	2.47E+01
		Copper		7.40E+01	5.18E+01
		Iron		2.10E+04	1.74E+04
		Lead		4.30E+01	3.39E+01
		Manganese		6.60E+02	4.85E+02
		Nickel		2.30E+01	1.80E+01
		Phosphorus		1.50E+03	1.07E+03
		Sodium		5.90E+02	4.19E+02
		Thallium		2.60E-01	2.04E-01
		Tin		<5.00E+00	<5.00E+00
		Zinc		2.30E+02	1.86E+02

Note:
Exposure point concentrations are based on measured data from July 2015.

Table E.3: Estimated Dose for Riparian Birds and Mammals at Frenchman's Bay (mg/kg·d)

COPC		Frenchman's Bay (mg/kg·d)				
		Muskrat	Trumpeter Swan	Bufflehead	Common Tern	Ring Billed Gull
Aluminum	max	9.97E+01	4.19E+01	4.49E+02	2.20E+01	7.22E+01
	UCLM	7.50E+01	3.15E+01	3.38E+02	1.66E+01	5.44E+01
Bismuth	max	1.22E-02	5.10E-03	3.87E-02	5.93E-03	1.29E-02
	UCLM	1.22E-02	5.10E-03	3.87E-02	5.93E-03	1.29E-02
Boron	max	6.60E-02	2.71E-02	2.49E-01	1.72E-02	6.22E-02
	UCLM	2.58E-02	1.03E-02	9.06E-02	6.86E-03	2.38E-02
Cadmium	max	5.89E-02	2.47E-02	1.49E-02	6.50E-04	1.38E-02
	UCLM	5.84E-02	2.45E-02	1.31E-02	5.33E-04	1.34E-02
Calcium	max	4.45E+04	1.87E+04	7.60E+03	8.15E+02	1.16E+04
	UCLM	4.01E+04	1.68E+04	6.59E+03	7.19E+02	1.04E+04
Chromium	max	9.22E-02	3.87E-02	9.71E-01	7.61E-02	1.80E-01
	UCLM	7.06E-02	2.96E-02	8.85E-01	7.05E-02	1.59E-01
Copper	max	2.07E+00	8.71E-01	9.97E-01	1.13E-01	6.73E-01
	UCLM	1.82E+00	7.63E-01	6.88E-01	8.84E-02	5.55E-01
Iron	max	5.73E+02	2.41E+02	8.06E+02	4.87E+01	2.41E+02
	UCLM	4.37E+02	1.84E+02	6.16E+02	3.72E+01	1.84E+02
Lead	max	6.31E-01	2.65E-01	4.96E-01	3.26E-02	2.08E-01
	UCLM	5.00E-01	2.10E-01	3.52E-01	2.32E-02	1.57E-01
Manganese	max	1.07E+02	4.50E+01	3.86E+01	3.32E+00	2.62E+01
	UCLM	8.84E+01	3.71E+01	3.09E+01	2.68E+00	2.14E+01
Nickel	max	7.73E-02	3.25E-02	2.73E-01	1.94E-02	6.74E-02
	UCLM	5.83E-02	2.45E-02	2.02E-01	1.46E-02	5.00E-02
Phosphorus	max	3.71E+00	1.56E+00	1.48E+01	9.53E-01	4.24E+00
	UCLM	2.44E+00	1.02E+00	9.68E+00	6.25E-01	2.78E+00
Sodium	max	5.02E+02	2.09E+02	3.01E+02	9.91E+01	2.72E+02
	UCLM	4.17E+02	1.74E+02	2.49E+02	8.24E+01	2.26E+02
Thallium	max	9.01E-01	3.78E-01	1.16E-01	1.90E-02	2.06E-01
	UCLM	9.00E-01	3.78E-01	1.15E-01	1.90E-02	2.06E-01
Tin	max	4.25E-02	1.78E-02	2.54E-01	3.54E-01	5.38E-01
	UCLM	4.25E-02	1.78E-02	2.54E-01	3.54E-01	5.38E-01
Zinc	max	3.68E+00	1.54E+00	7.19E+00	4.55E+00	9.76E+00
	UCLM	2.94E+00	1.23E+00	5.63E+00	3.69E+00	7.85E+00

Note:
All doses are based on measured water and sediment data from July 2015.
[1] Dose for phosphorous is based on sediment exposure only.

E.3 Effects Assessment

All aquatic benchmarks are summarized in Table E.4, and were generally Lowest Chronic Values (LCVs) obtained from Suter and Tsao (1996). Borgmann et al. (2005) performed acute toxicity tests with *Hyalella azteca* for 63 metals in hard and soft water. Acute LC_{50} values for boron and bismuth were taken from Borgmann et al. (2005) and converted to chronic EC_{20}s (using a conversion factor of 10 (EC/HC, 2003)). For assessment of benthic invertebrates, toxicity benchmarks have been presented as water concentrations; however, benthic invertebrates may reside in the water column and in sediment. As such, sediment toxicity benchmarks are presented for COPCs with MOECC LELs or CCME ISQGs for assessment of benthic invertebrates (Table E.5).

The benchmark values for riparian birds and mammals are based on doses. The benchmark doses used were generally the lowest observed adverse effect level (LOAEL) values from Sample et al. (1996). The mammal and bird benchmarks used are summarized in Table E.6 and E.7, respectively.

Major ions (Ca, Mg, Na) were considered to be essentially non-toxic for birds and mammals. They are effectively regulated in the body and have not been associated with adverse effects in birds and mammals at environmental concentrations. Phosphorus was also considered to be essentially non-toxic. It exists in the environment as phosphate, where it acts as a nutrient, and has not been associated with adverse effects in birds and mammals.

Table E.4: Toxicological Benchmarks for Aquatic Receptors

COPC	Receptor	Water TRV (mg/L)	Endpoint	Test Species	Reference
Aluminum	Fish and Frog	3.29E+00	LCV	28-day embryo-larval tests with *Pimephales promelas*	Kimball, n.d. (cited in Suter and Tsao, 1996)
	Aquatic Plant	4.60E-01	LCV	4-day *Selenastrum capricornutum*	EPA, 1988 (cited in Suter and Tsao, 1996)
	Benthic Invertebrate	1.90E+00	LCV	*Daphnia magna*	McCauley et al., 1986 (cited in Suter and Tsao, 1996)
Bismuth	Fish and Frog	none	-	-	-
	Aquatic Plant	7.2	LOEC	*Chlorella vulgaris*	den Dooren de Jong, 1965 (cited in Alpine 2010)
	Benthic Invertebrate	0.0025	acute LC50 converted to chronic EC20	1 week test with *Hyalella azteca*	Borgmann et al., 2005
Boron	Fish and Frog	1.34	LOEC	28-day embryo survival with Rainbow Trout *Oncorhynchus mykiss*	Black et al., 1993 (cited in CCME 2009)

COPC	Receptor	Water TRV (mg/L)	Endpoint	Test Species	Reference
	Aquatic Plant	3.5	LOEC	Duckweed (*Spirodella polyrrhiza*)	Davis et al., 2002 (cited in CCME, 2009)
	Benthic Invertebrate -	8.83	LCV	21-day test with *Daphnia magna*	Lewis and Valentine, 1981 (cited in Suter and Tsao, 1996)
Cadmium	Fish and Frog	1.70E-03	LCV	Early life stage test with *Salvelinus fontinalis*	Sauter et al., 1976 (cited in Suter and Tsao, 1996)
	Aquatic Plant	2.00E-03	LCV	-	Conway, 1977 (cited in Suter and Tsao, 1996)
	Benthic Invertebrate	1.50E-04	LCV	Reproduction with *Daphnia magna*	Chapman et al., n.d. (cited in Suter and Tsao, 1996)
Calcium	Fish and Frog	none	-	-	-
	Aquatic Plant	none	-	-	-
	Benthic Invertebrate	116	LCV	21-day test with *Daphnia magna*	Biesinger and Christensen, 1972 (cited in Suter and Tsao, 1996)
Chromium	Fish and Frog	6.83E-02	LCV	Early life stages with Rainbow Trout	Stevens and Chapman, 1984 (cited in Suter and Tsao, 1996)
	Aquatic Plant	3.97E-01	LCV	4-day growth inhibition test with *Selenastrum capricornutum*	EPA, 1985 (cited in Suter and Tsao, 1996)
	Benthic Invertebrate	4.40E-02	LCV	Life-cycle test with *Daphnia magna*	Chapman et al., n.d. (cited in Suter and Tsao, 1996)
Copper	Fish and Frog	3.80E-03	LCV	Early life stage test with Brook Trout (*Salvelinus fontinalis*)	Sauter et al., 1976 (cited in Suter and Tsao, 1996)
	Aquatic Plant	2.00E-03	Water quality guideline	-	CCME, 1999
	Benthic Invertebrate	6.07E-03	LCV	*Gammarus pseudolimnaeus*	Arthur and Leonard, 1970, (cited in Suter and Tsao, 1996)
Iron	Fish and Frog	1.30E+00	LCV	Mortality with Rainbow Trout	Amelung, 1981 (cited in Suter and Tsao, 1996)
	Aquatic Plant	1.49E+00	EC50 converted to EC20	Growth with *Lemna minor*	Wang, 1986 (cited in BC MOE, 2008)
	Benthic Invertebrate	3.00E-01	Water quality guideline	-	CCME, 1999

COPC	Receptor	Water TRV (mg/L)	Endpoint	Test Species	Reference
Lead	Fish and Frog	1.89E-02	LCV	Early life stage with Rainbow Trout	Davies et al., 1976 (cited in Suter and Tsao, 1996)
	Aquatic Plant	5.00E-01	LCV	Growth inhibition with *Chlorella vulgaris*, *Scenedesmus quadricauda*, and *Selenastrum capricornutum*	EPA, 1985 (cited in Suter and Tsao, 1996)
	Benthic Invertebrate	2.55E-02	LCV	21-day test with *Daphnia magna*	Chapman et al. (manuscript), (cited in Suter and Tsao, 1996)
Manganese	Fish and Frog	1.78E+00	LCV	28-day early life-stage test with *Pimephales promelas*	Kimball, n.d. (cited in Suter and Tsao, 1996)
	Aquatic Plant	4.98	EC50 converted to EC20	12-day population effects on the green algae (*Scenedesmus quadricauda*)	Fargasova et al., 1999
	Benthic Invertebrate	1.10E+00	LCV	-	Kimball, n.d. (cited in Suter and Tsao, 1996)
Nickel	Fish and Frog	3.50E-02	LCV	Early life stage test on Rainbow Trout	Nebeker et al., 1985 (cited in Suter and Tsao, 1996)
	Aquatic Plant	5.00E-03	LCV	Inhibition with *Microcystis aeruginosa*	EPA, 1986 (cited in Suter and Tsao, 1996)
	Benthic Invertebrate	1.28E-01	LCV	Life cycle test with *Daphnia magna*	Lazareva, 1985 (cited in Suter and Tsao, 1996)
Phosphorus	Fish and Frog	0.0017	LC50 converted to EC20	26-day LC50 with Channel fish (*Ictalurus punctatus*)	Bentley et al., 1978
	Aquatic Plant	3	LOEC	21-day population effects with the Blue-Green Algae	Qiu et al., 2013.
	Benthic Invertebrate	0.004	LC50 converted to EC20	8-day mortality test with *Daphnia magna*	Bentley et al., 1978
Sodium	Fish and Frog	1.15E+02	EC_{10} (Na component of Na_2SO_4)	Developmental effects on *Oncorhynchus mykiss*	Elphick et al, 2011
	Aquatic Plant	1.71E+02	EC_{25} (Na component of Na_2SO_4)	Growth of *Fontinalis antipyretica*	Elphick et al, 2011
	Benthic Invertebrate	6.80E+02	LCV	Reproductive effects on *Daphnia magna*	Biesinger and Christensen, 1972 (cited in Suter and Tsao, 1996)
Thallium	Fish and Frog	5.70E-02	LCV	Embryo-larval tests with *Pimephales promelas*	Kimball, n.d. (cited in Suter and Tsao, 1996)
	Aquatic Plant	1.00E-01	LCV	4-day EC50 with *Selenastrum capricornutum*	EPA, 1978 (cited in Suter and Tsao, 1996)

COPC	Receptor	Water TRV (mg/L)	Endpoint	Test Species	Reference
	Benthic Invertebrate	1.30E-01	LCV	28-day tests with *Daphnia magna*	Kimball, n.d. (cited in Suter and Tsao, 1996)
Tin	Fish and Frog	none	-	-	-
	Aquatic Plant	none	-	-	-
	Benthic Invertebrate	3.50E-01	LCV	21-day reproductive test with *Daphnia magna*	Biesinger and Christensen (1972).
Zinc	Fish and Frog	3.64E-02	LCV	Life-cycle tests with *Jordanella floridae*	Spehar, 1976 (cited in Suter and Tsao, 1996)
	Aquatic Plant	3.00E-02	LCV	7-day growth tests with *Selenastrum capricornutum*	Bartlett et al., 1974 (cited in Suter and Tsao, 1996)
	Benthic Invertebrate	5.24E+00	LCV	Life-cycle tests with *Daphnia magna*.	Chapman et al., n.d. (cited in Suter and Tsao, 1996)

Table E.5: Toxicological Benchmarks for Benthic Invertebrates

COPC	Benthic Invertebrate (mg/kg dw)	Reference
Cadmium	0.6	Sediment LEL (MOE, 2011)
Chromium	26	Sediment LEL (MOE, 2011)
Copper	16	Sediment LEL (MOE, 2011)
Iron	21200	Sediment LEL (MOE, 2011)
Lead	31	Sediment LEL (MOE, 2011)
Manganese	460	Sediment LEL (MOE, 2011)
Nickel	16	Sediment LEL (MOE, 2011)
Phosphorus	600	Sediment LEL (MOE, 2011)
Zinc	120	Sediment LEL (MOE, 2011)

Table E.6: Selected Toxicity Reference Values for Mammals (Riparian and Terrestrial)

COPC	Mammal LOAEL (mg/kg d)	Test Species	Endpoint	Test Duration	Reference
Aluminum	1.93E+01	mouse	reproduction	3 generations	Ondreicka et al., 1966 (cited in Sample et al., 1996)
Bismuth	none	-	-	-	-
Boron	9.36E+01	rat	reproduction	3 generations	Weir and Fisher, 1972 (cited in Sample et al., 1996)
Cadmium	1.00E+01	rat	reproduction	6 weeks	Sutou et al., 1980 (cited in Sample et al., 1996)
Chromium	2737 (NOAEL)	rat	reproduction/ longevity	2 years	Ivankovic and Preussmann, 1975 (cited in Sample et al., 1996)
Copper	1.51E+01	mink	reproduction	375 days	Aulerich et al., 1982 (cited in Sample et al., 1996)

COPC	Mammal LOAEL (mg/kg-d)	Test Species	Endpoint	Test Duration	Reference
Iron	none	-	-	-	-
Lead	8.00E+01	rat	reproduction	3 generations	Azar et al., 1973 (cited in Sample et al., 1996)
Manganese	2.84E+02	rat	reproduction	critical life stage (224 days)	Laskey et al., 1982 (cited in Sample et al., 1996)
Nickel	80	rat	reproduction	3 generations	Ambrose et al., 1976 (cited in Sample et al., 1996)
Thallium	7.40E-02	rat	reproduction	60 days (critical life stage)	Formigli et al., 1986 (cited in Sample et al., 1996)
Tin	35	mouse	reproduction	days 6 - 15 of gestation	Davis et al., 1987 (cited in Sample et al., 1996)
Zinc	3.20E+02	rat	reproduction	days 1-16 of gestation	Schlicker and Cox, 1968 (cited in Sample et al., 1996)

Table E.7: Selected Toxicity Reference Values for Riparian and Terrestrial Birds

COPC	Bird LOAEL (mg/kg-d)	Test Species	Endpoint	Test Duration	Reference
Aluminum	1.10E+02	Ringed Dove	reproduction	4 months	Carriere et al., 1986 (cited in Sample et al., 1996)
Bismuth	none	-	-	-	-
Boron	1.00E+02	Mallard	reproduction	3 weeks prior to, during, and 3 weeks post reproduction	Smith and Anders, 1989 (cited in Sample et al., 1996)
Cadmium	2.00E+01	Mallard	reproduction	critical life stage (90 days)	White and Finley, 1978 (cited in Sample et al., 1996)
Chromium	5.00E+00	Black Duck	reproduction	critical life stage (10 months)	Haseltine et al., unpubl. Data, (cited in Sample et al., 1996)
Copper	6.17E+01	1 day old chicks	growth, mortality	10 weeks	Mehring et al., 1960 (cited in Sample et al., 1996)
Iron	none	-	-	-	-
Lead	1.13E+01	Japanese Quail	reproduction	12 weeks	Edens et al., 1976 (cited in Sample et al., 1996)
Manganese	977 (NOAEL)	Japanese Quail	growth, aggressive behaviour	75 days	Laskey and Edens, 1985 (cited in Sample et al., 1996)
Nickel	107	Mallard (duckling)	growth/ mortality	90 days	Cain and Pafford, 1981 (cited in Sample et al., 1996)
Thallium	none	-	-	-	-
Tin	16.9	Japanese Quail	reproduction	6 weeks	Schlatterer et al., 1993 (cited in Sample et al., 1996)
Zinc	1.31E+02	White Leghorn hens	reproduction	44 weeks	Stahl et al., 1990 (cited in Sample et al., 1996)

E.4 Risk Characterization

Ecological risk is estimated by dividing the exposure value (EV) by the benchmark value (BV) for a given COPC and receptor species, yielding a hazard quotient (HQ). When the EV for an organism at a site exceeds the BV (HQ > 1), a potential for adverse ecological effects is inferred. A summary of HQs for aquatic receptors at Frenchman's Bay is presented in Table E.8. The HQs greater than 1 are presented in bold. Toxicity benchmarks are not available for a number of COPCs. HQs have not been calculated for those COPCs and are shown in the table as 'nd' for no data.

Based on the results for Frenchman's Bay, aluminum and thallium exceed an HQ of 1 for Muskrats; aluminum exceeds an HQ of 1 for the Bufflehead; copper exceeds an HQ of 1 for aquatic plants; and iron exceeds an HQ of 1 for benthic invertebrates.

Sediment concentrations exceed sediment toxicity benchmarks for benthic invertebrates for the majority of metals including cadmium, chromium, copper, lead, manganese, nickel, phosphorus, and zinc. Exceedances of toxicity benchmarks are not uncharacteristic for an area such as Frenchman's Bay that is highly influenced by urban runoff.

The following section estimates the contribution to risk at Frenchman's Bay for substances released from the PN site.

Table E.8: Hazard Quotients for Aquatic and Riparian Biota at Frenchman's Bay

Parameter		Fish	Frog (Tadpole)	Benthic Invertebrate	Aquatic Plant	Muskrat	Trumpeter Swan	Bufflehead	Common Tern	Ring Billed Gull
Aluminum	max	8.2E-02	8.2E-02	1.4E-01	5.9E-01	**5.2E+00**	3.8E-01	**4.1E+00**	2.0E-01	6.6E-01
	UCLM	6.2E-02	6.2E-02	1.1E-01	4.4E-01	**3.9E+00**	2.9E-01	**3.1E+00**	1.5E-01	4.9E-01
Bismuth	max	nd	nd	4.0E-01	1.4E-04	nd	nd	nd	nd	nd
	UCLM	nd	nd	4.0E-01	1.4E-04	nd	nd	nd	nd	nd
Boron	max	3.1E-02	3.1E-02	4.8E-03	1.2E-02	7.0E-04	2.7E-04	2.5E-03	1.7E-04	6.2E-04
	UCLM	2.9E-02	2.9E-02	4.4E-03	1.1E-02	2.8E-04	1.0E-04	9.1E-04	6.9E-05	2.4E-04
Cadmium	max	5.9E-03	5.9E-03	6.7E-02	5.0E-03	5.9E-03	1.2E-03	7.5E-04	3.2E-05	6.9E-04
	UCLM	5.9E-03	5.9E-03	6.7E-02	5.0E-03	5.8E-03	1.2E-03	6.6E-04	2.7E-05	6.7E-04
Calcium	max	nd	nd	5.5E-01	nd	N/A	N/A	N/A	N/A	N/A
	UCLM	nd	nd	5.0E-01	nd	N/A	N/A	N/A	N/A	N/A
Chromium	max	7.3E-02	7.3E-02	1.1E-01	1.3E-02	3.4E-05	7.7E-03	1.9E-01	1.5E-02	3.6E-02
	UCLM	7.3E-02	7.3E-02	1.1E-01	1.3E-02	2.6E-05	5.9E-03	1.8E-01	1.4E-02	3.2E-02
Copper	max	5.5E-01	5.5E-01	3.5E-01	**1.1E+00**	1.4E-01	1.4E-02	1.6E-02	1.8E-03	1.1E-02
	UCLM	5.0E-01	5.0E-01	3.1E-01	9.5E-01	1.2E-01	1.2E-02	1.1E-02	1.4E-03	9.0E-03
Iron	max	4.3E-01	4.3E-01	**1.9E+00**	3.8E-01	nd	nd	nd	nd	nd
	UCLM	3.3E-01	3.3E-01	**1.4E+00**	2.9E-01	nd	nd	nd	nd	nd
Lead	max	4.9E-02	4.9E-02	3.6E-02	1.8E-03	7.9E-03	2.3E-02	4.4E-02	2.9E-03	1.8E-02
	UCLM	4.0E-02	4.0E-02	2.9E-02	1.5E-03	6.2E-03	1.9E-02	3.1E-02	2.1E-03	1.4E-02
Manganese	max	4.5E-02	4.5E-02	7.3E-02	1.6E-02	3.8E-01	4.6E-02	4.0E-02	3.4E-03	2.7E-02
	UCLM	3.7E-02	3.7E-02	6.0E-02	1.3E-02	3.1E-01	3.8E-02	3.2E-02	2.7E-03	2.2E-02
Nickel	max	3.7E-02	3.7E-02	1.0E-02	2.6E-01	9.7E-04	3.0E-04	2.6E-03	1.8E-04	6.3E-04
	UCLM	3.2E-02	3.2E-02	8.8E-03	2.3E-01	7.3E-04	2.3E-04	1.9E-03	1.4E-04	4.7E-04
Phosphorus	max	nd	nd	nd	nd	N/A	N/A	N/A	N/A	N/A
	UCLM	nd	nd	nd	nd	N/A	N/A	N/A	N/A	N/A

Parameter		Fish	Frog (Tadpole)	Benthic Invertebrate	Aquatic Plant	Muskrat	Trumpeter Swan	Bufflehead	Common Tern	Ring-Billed Gull
Sodium	max	7.9E-01	7.9E-01	1.3E-01	5.3E-01	N/A	N/A	N/A	N/A	N/A
	UCLM	6.6E-01	6.6E-01	1.1E-01	4.4E-01	N/A	N/A	N/A	N/A	N/A
Thallium	max	8.8E-04	8.8E-04	3.8E-04	5.0E-04	**1.2E+01**	nd	nd	nd	nd
	UCLM	8.8E-04	8.8E-04	3.8E-04	5.0E-04	**1.2E+01**	nd	nd	nd	nd
Tin	max	nd[1]	nd[1]	2.9E-03	nd[1]	1.2E-03	1.1E-03	1.5E-02	2.1E-02	3.2E-02
	UCLM	nd[1]	nd[1]	2.9E-03	nd[1]	1.2E-03	1.1E-03	1.5E-02	2.1E-02	3.2E-02
Zinc	max	2.0E-01	2.0E-01	1.4E-03	2.5E-01	1.1E-02	1.2E-02	5.5E-02	3.5E-02	7.4E-02
	UCLM	1.7E-01	1.7E-01	1.1E-03	2.0E-01	9.2E-03	9.4E-03	4.3E-02	2.8E-02	6.0E-02

Note:
Bold and shaded values indicate a HQ > 1
nd = no data
Ca, Na, and P are considered non-toxic to birds and mammals; therefore have been labelled as not applicable (N/A).
The HQs for thallium are equivalent since data are based on non-detects.

E.5 Discussion of PN Contribution

A surface water model has been prepared, based on current and temperature data from 2011 and 2012, to predict water concentrations at the inlet to Frenchman's Bay and Ajax WTP based on a tracer concentration for any contaminant of 1 mg/L (Golder and EcoMetrix, 2017). A mass-balance model has also been used to predict concentrations in Frenchman's Bay, assuming a completely mixed embayment, with inputs from lake exchange and tributaries. Based on the surface water model and mass balance model, the dilution factors for PN U1-4 and U5-8 releases at the inlet to Frenchman's Bay and inside the bay are approximately 7 and 9 respectively. Water and sediment samples were collected from north and south ends of Frenchman's Bay. The data have been pooled together as there is not much variability in measurements.

Water samples were collected from the PN discharge channels during July and August 2015 as part of the baseline environmental monitoring program. The 2015 water sampling campaign included sampling of Frenchman's Bay and Lake Ontario water during the first event (July 22-24, 2015), and a second event where only lake water was sampled (August 27, 2015). These events occurred during the summer months when there is typically low rainfall and reduced urban runoff from stormwater sources. A review of historical weather data for the nearby Oshawa weather station indicates that the Frenchman's Bay sampling event was completed on dates with no rainfall, and only a small amount of rainfall (5.1mm) in the week prior to the sampling event (Government of Canada, 2022). Based on this review, the Frenchman's Bay samples are expected to represent a period where influence to Frenchman's Bay from urban runoff was low.

A dilution factor of 9 was applied to the maximum and UCLM water concentrations from the discharge channels in order to determine the expected concentration inside Frenchman's Bay due to releases from PN. Table E.9 presents the comparison between measured water concentrations at Frenchman's Bay and estimated water concentrations at Frenchman's Bay based on water concentrations in the PN discharge channels and a dilution factor of approximately 9 to inside Frenchman's Bay. The percent contribution from PN ranges from 0.3% to 22%. Overall, the contribution to the total concentration of metals at Frenchman's Bay from PN is low. Table E.10 summarizes the HQs to receptors at Frenchman's Bay for the PN component of risk. Overall, all HQs for the PN component are below 1 with the exception of thallium for Muskrats where the HQ is slightly above 1. The acceptable risk level (HQ) for thallium is exceeded due to sediment ingestion for the Muskrat. Contribution from PN to Frenchman's Bay sediment was assumed to be equal to that of water; however, for some parameters such as thallium, water concentrations were below the detection limit; therefore, the contribution from PN may be overestimated.

Table E.9: Measured Water Concentrations at Frenchman's Bay Compared to PN Contribution

	Frenchman's Bay Measured Concentration (mg/L)		Pickering Measured Concentration (mg/L)		Estimated Pickering Contribution at Frenchman's Bay (mg/L)		% Contribution from PN	
COPC	Max	UCLM	Max	UCLM	Max	UCLM	Max %	UCLM %
Aluminum	2.7E-01	2.0E-01	9.6E-03	8.7E-03	1.1E-03	1.0E-03	0.4%	0.5%
Bismuth	1.0E-03	1.0E-03	<1.0E-03	<1.0E-03	1.2E-04	1.2E-04	11.6%	11.6%
Boron	4.2E-02	3.9E-02	2.7E-02	2.6E-02	3.1E-03	3.0E-03	7.5%	7.8%
Cadmium	1.0E-05	1.0E-05	1.9E-05	1.4E-05	2.2E-06	1.7E-06	22.1%	16.5%
Calcium	6.4E+01	5.8E+01	3.5E+01	3.5E+01	4.1E+00	4.0E+00	6.4%	7.0%
Chromium	<5.0E-03	<5.0E-03	<5.0E-03	<5.0E-03	<5.8E-04	<5.8E-04	11.6%	11.6%
Copper	2.1E-03	1.9E-03	2.0E-03	1.7E-03	2.3E-04	2.0E-04	11.1%	10.3%
Iron	5.6E-01	4.3E-01	<1.0E-01	<1.0E-01	1.2E-02	1.2E-02	2.1%	2.7%
Lead	9.2E-04	7.5E-04	<5.0E-04	<5.0E-04	5.8E-05	5.8E-05	6.3%	7.8%
Manganese	8.0E-02	6.6E-02	<2.0E-03	<2.0E-03	2.3E-04	2.3E-04	0.3%	0.4%
Nickel	1.3E-03	1.1E-03	1.2E-03	1.1E-03	1.4E-04	1.3E-04	10.7%	11.9%
Sodium	9.1E+01	7.6E+01	1.4E+01	1.4E+01	1.6E+00	1.6E+00	1.8%	2.2%
Thallium	<5.0E-05	<5.0E-05	<5.0E-05	<5.0E-05	<5.8E-06	<5.8E-06	11.6%	11.6%
Tin	<1.0E-03	<1.0E-03	<1.0E-03	<1.0E-03	<1.2E-04	<1.2E-04	11.6%	11.6%
Zinc	7.4E-03	6.0E-03	5.5E-03	5.2E-03	6.4E-04	6.1E-04	8.7%	10.1%

Table E.10: PN Component of Hazard Quotients for Aquatic Biota at Frenchman's Bay

Parameter		Fish	Frog (Tadpole)	Benthic Invertebrate	Aquatic Plant	Muskrat	Trumpeter Swan	Bufflehead	Common Tern	Ring-Billed Gull
Aluminum	max	3.4E-04	3.4E-04	5.9E-04	2.4E-03	2.1E-02	1.6E-03	1.7E-02	8.3E-04	2.7E-03
	UCLM	3.1E-04	3.1E-04	5.3E-04	2.2E-03	1.9E-02	1.4E-03	1.5E-02	7.5E-04	2.5E-03
Bismuth	max	nd	nd	4.7E-02	1.6E-05	nd	nd	nd	nd	nd
	UCLM	nd	nd	4.7E-02	1.6E-05	nd	nd	nd	nd	nd
Boron	max	2.3E-03	2.3E-03	3.6E-04	9.0E-04	5.3E-05	2.0E-05	1.9E-04	1.3E-05	4.7E-05
	UCLM	2.3E-03	2.3E-03	3.4E-04	8.6E-04	2.2E-05	8.1E-06	7.1E-05	5.4E-06	1.9E-05
Cadmium	max	1.3E-03	1.3E-03	1.5E-02	1.1E-03	1.3E-03	2.7E-04	1.6E-04	7.2E-06	1.5E-04
	UCLM	9.7E-04	9.7E-04	1.1E-02	8.3E-04	9.6E-04	2.0E-04	1.1E-04	4.4E-06	1.1E-04
Calcium	max	nd	nd	3.5E-02	nd	N/A	N/A	N/A	N/A	N/A
	UCLM	nd	nd	3.5E-02	nd	N/A	N/A	N/A	N/A	N/A
Chromium	max	8.5E-03	8.5E-03	1.3E-02	1.5E-03	3.9E-06	9.0E-04	2.3E-02	1.8E-03	4.2E-03
	UCLM	8.5E-03	8.5E-03	1.3E-02	1.5E-03	3.0E-06	6.9E-04	2.1E-02	1.6E-03	3.7E-03
Copper	max	6.1E-02	6.1E-02	3.8E-02	1.2E-01	1.5E-02	1.6E-03	1.8E-03	2.0E-04	1.2E-03
	UCLM	5.1E-02	5.1E-02	3.2E-02	9.8E-02	1.2E-02	1.3E-03	1.2E-03	1.5E-04	9.3E-04
Iron	max	9.0E-03	9.0E-03	3.9E-02	7.9E-03	nd	nd	nd	nd	nd
	UCLM	9.0E-03	9.0E-03	3.9E-02	7.9E-03	nd	nd	nd	nd	nd
Lead	max	3.1E-03	3.1E-03	2.3E-03	1.2E-04	5.0E-04	1.5E-03	2.8E-03	1.8E-04	1.2E-03
	UCLM	3.1E-03	3.1E-03	2.3E-03	1.2E-04	4.9E-04	1.4E-03	2.4E-03	1.6E-04	1.1E-03
Manganese	max	1.3E-04	1.3E-04	2.1E-04	4.7E-05	1.1E-03	1.3E-04	1.2E-04	9.9E-06	7.8E-05
	UCLM	1.3E-04	1.3E-04	2.1E-04	4.7E-05	1.1E-03	1.3E-04	1.1E-04	9.6E-06	7.7E-05
Nickel	max	4.0E-03	4.0E-03	1.1E-03	2.8E-02	1.0E-04	3.3E-05	2.7E-04	2.0E-05	6.8E-05
	UCLM	3.8E-03	3.8E-03	1.0E-03	2.7E-02	8.6E-05	2.7E-05	2.2E-04	1.6E-05	5.5E-05
Phosphorus	max	nd	nd	nd	nd	N/A	N/A	N/A	N/A	N/A
	UCLM	nd	nd	nd	nd	N/A	N/A	N/A	N/A	N/A

Parameter		Fish	Frog (Tadpole)	Benthic Invertebrate	Aquatic Plant	Muskrat	Trumpeter Swan	Bufflehead	Common Tern	Ring-Billed Gull
Sodium	max	1.4E-02	1.4E-02	2.4E-03	9.5E-03	N/A	N/A	N/A	N/A	N/A
	UCLM	1.4E-02	1.4E-02	2.4E-03	9.5E-03	N/A	N/A	N/A	N/A	N/A
Thallium	max	1.0E-04	1.0E-04	4.5E-05	5.8E-05	**1.4E+00**	nd	nd	nd	nd
	UCLM	1.0E-04	1.0E-04	4.5E-05	5.8E-05	**1.4E+00**	nd	nd	nd	nd
Tin	max	nd	nd	3.3E-04	nd	1.4E-04	1.2E-04	1.7E-03	2.4E-03	3.7E-03
	UCLM	nd	nd	3.3E-04	nd	1.4E-04	1.2E-04	1.7E-03	2.4E-03	3.7E-03
Zinc	max	1.8E-02	1.8E-02	1.2E-04	2.1E-02	9.9E-04	1.0E-03	4.7E-03	3.0E-03	6.4E-03
	UCLM	1.7E-02	1.7E-02	1.2E-04	2.0E-02	9.3E-04	9.5E-04	4.4E-03	2.9E-03	6.1E-03

Note:
Ca, Na, and P are considered non-toxic to birds and mammals; therefore, have been labelled as not applicable (N/A).
Bold and shaded values indicate a HQ > 1
nd = indicates no data are available.

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Appendix F Summary of Data from Baseline Environmental Sampling Program

Table F.1: Lake Ontario Surface Water Data

Analyte	Unit	Detection Limit	LWC-1	LWC-1	LWC-1	LWC-1	LW-10	LW-10	LW-10	LW-21	LW-21	LW-21	LW-21	LW-9	LW-9	LW-9	LW-9
			22/07/2015	22/07/2015	27/08/2015	27/08/2015	23/07/2015	23/07/2015	27/08/2015	23/07/2015	23/07/2015	27/08/2015	27/08/2015	23/07/2015 (3)	23/07/2015 (3)	27/08/2015	27/08/2015
			LWC-1-0.3	LWC-1-5	LWC-1-0.3	LWC-1-5	LW-10	DUP-2 (Field Duplicate)	LW-10	LW-21	DUP-1 (Field Duplicate)	LW-21	DUP-1 (Field Duplicate)	LW-9-0.3	LW-9-5	LW-9-0.3	DUP-3 (Field Duplicate)
General Chem																	
Alkalinity (Total as CaCO3)	mg/L	1	91	92	93	96	93	93	96	93	94	96	96	93	92	96	95
Ammonia Nitrogen	mg/L	0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Unionized Ammonia, calculated	mg/L	0.0032	<0.0023	<0.0017	<0.0013	<0.0010	<0.0016	<0.0016	<0.0017	<0.0013	<0.0013	<0.0020	<0.0017	<0.0010	<0.0017	<0.0014	<0.0014
Biochemical Oxygen Demand, 5 Day	mg/L	2	3.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	3.0	3.0	<2.0	<2.0
Chemical Oxygen Demand	mg/L	4	<4.0	9.6	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	5.8	4.6	<4.0	<4.0	<4.0	6.2	<4.0
Conductivity	ms/cm	0.001	0.31	0.31	0.316	0.318	0.32	0.32	0.315	0.32	0.32	0.316	0.316	0.32	0.32	0.315	0.314
Conductivity, field measured	ms/cm		0.226	0.204	0.302	0.302	0.291	0.291	0.305	0.289	0.289	0.307	0.307	0.287	0.288	0.304	0.304
Hardness, Calcium Carbonate	mg/L	1	120	120	130	140	120	130	140	120	120	130	140	130	130	140	130
Temperature, field measured	C		14.15	10.03	12.2	12.94	18.45	18.45	19.38	16.84	16.84	23.11	21.11	12.41	7.83	15.5	15.5
Total Suspended Solids	mg/L	1	<1.0	<1.0	<10.0	<10.0	<1	<1	<10	<1	<1	<10	<10	<1	<1	<10	<10
pH	pH units		7.97	8.13	7.73	7.78	8.04	8.08	7.7	8.01	8.09	7.72	7.71	8.06	8.02	7.61	7.72
pH, field measured	pH units		8.27	8.27	8.08	7.94	7.97	7.97	7.96	7.94	7.94	7.92	7.92	7.96	8.34	8	8
Total Residual Chlorine, field measured	mg/L	0.0012	<0.0012	<0.0012	<0.0012	<0.0012	<0.0012	<0.0012	<0.0012	<0.0012	<0.0012	<0.0012	<0.0012	<0.0012	<0.0012	<0.0012	<0.0012
Metals/Metalloids																	
Aluminum	mg/L	0.005	0.01	0.0053	0.008	<0.0050	0.0057	0.0096	0.0063	0.0072	0.0088	0.0075	0.0058	0.0063	0.0073	0.007	0.009
Aluminum, filtered	mg/L	0.005	0.021	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Antimony	mg/L	0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Arsenic	mg/L	0.001	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Barium	mg/L	0.002	0.023	0.022	0.022	0.022	0.022	0.022	0.021	0.023	0.023	0.021	0.023	0.023	0.023	0.022	0.022
Beryllium	mg/L	0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.00050	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Bismuth	mg/L	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Boron	mg/L	0.01	0.026	0.025	0.026	0.025	0.027	0.024	0.024	0.025	0.026	0.024	0.024	0.025	0.026	0.025	0.025
Cadmium	mg/L	0.0001	0.000014	0.000014	<0.000005	<0.000005	<0.000010	<0.000010	<0.000005	0.00001	<0.000010	<0.000005	0.000019	<0.000010	0.000013	<0.000005	<0.000005
Calcium	mg/L	0.2	35	34	34	33	35	34	33	34	35	33	33	35	35	34	34
Chromium	mg/L	0.005	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Cobalt	mg/L	0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Copper	mg/L	0.001	<0.0010	<0.0010	<0.0010	<0.0010	0.002	0.0013	<0.0010	<0.0010	0.0017	0.0012	<0.0010	0.0013	0.001	<0.0010	<0.0010
Lead	mg/L	0.1	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Lithium	mg/L	0.0005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Magnesium	mg/L	0.005	8.9	8.5	9.1	8.6	8.7	8.6	8.5	8.8	8.9	8.6	8.7	8.8	8.9	8.7	8.5
Manganese	mg/L	0.05	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020
Mercury	mg/L	0.0001	<0.0001	<0.0001	0.00001	0.00001	<0.0001	<0.0001	<0.00001	<0.0001	<0.0001	0.00001	<0.00001	<0.0001	<0.0001	<0.00001	<0.00001
Molybdenum	mg/L	0.002	0.0014	0.0014	0.0012	0.0012	0.0014	0.0012	0.0012	0.0013	0.0014	0.0011	0.0013	0.0013	0.0013	0.0012	0.0012
Nickel	mg/L	0.0005	<0.0010	<0.0010	0.0011	<0.0010	0.001	<0.0010	0.0012	0.0012	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Potassium	mg/L	0.001	1.6	1.6	1.7	1.6	1.6	1.6	1.6	1.6	1.7	1.6	1.6	1.6	1.6	1.6	1.6
Selenium	mg/L	0.2	0.00017	0.00013	0.000129	0.000126	0.0002	0.00016	0.00012	0.0001	0.00015	0.000149	0.000115	0.00021	0.0002	0.000123	0.000131
Silicon	mg/L	0.05	0.19	0.27	0.27	0.31	0.36	0.35	0.29	0.35	0.36	0.25	0.26	0.33	0.35	0.21	0.2
Silver	mg/L	0.002	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Sodium	mg/L	0.0001	14	14	16	14	14	14	14	14	14	14	14	14	14	14	14
Strontium	mg/L	0.1	0.18	0.18	0.18	0.18	0.18	0.18	0.17	0.18	0.18	0.17	0.18	0.18	0.18	0.18	0.18
Tellurium	mg/L	0.001	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Thallium	mg/L	0.001	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050
Tin	mg/L	0.00005	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Titanium	mg/L	0.001	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Tungsten	mg/L	0.005	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Uranium	mg/L	0.001	0.00042	0.00037	0.00035	0.00033	0.0004	0.0004	0.00034	0.00042	0.00041	0.00035	0.00034	0.00041	0.00039	0.00034	0.00034
Vanadium	mg/L	0.0001	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Zinc	mg/L	0.0005	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	0.0055	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Zirconium	mg/L	0.005	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Iron	mg/L	0.001	<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	<0.1
PetrHydroCarb																	
Petroleum Hydrocarbons - F1 (C6-C10)-BTEX	mg/L	0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Petroleum Hydrocarbons - F1 (C6-C10)	mg/L	0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Petroleum Hydrocarbons - F2 (C10-C16)	mg/L	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	<0.1	<0.1
Petroleum Hydrocarbons - F3 (C16-C34)	mg/L	0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Petroleum Hydrocarbons - F4 (C34-C50)	mg/L	0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Other																	
Morpholine	mg/L	0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	0.006	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
Hydrazine	mg/L																
Radionuclides																	
Tritium	Bq/L	4.4	<4.5	<4.5	<4.2	<4.2	17.2	16.6	49.6	22.1	23.4	69.1	65.3	<20	<20	8.9	4.9
Carbon-14	Bq/L	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	<0.1	<0.1
Cobal-60	Bq/L	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	<0.1	<0.1
Cesium-134	Bq/L	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.3	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Cesium-137	Bq/L	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	<0.1	<0.1

Table F.1: Lake Ontario Surface Water Data

Analyte	Unit	Detection Limit	LW-9	LWE-1	LWE-1	LWE-1	LWE-1	FB-1	FB-1	FB-1	FB-1	FB-1	FB-1
			27/08/2015	**23/07/2015**	**23/07/2015**	**27/08/2015**	**27/08/2015**	**23/07/2015**	**23/07/2015** (3)	**23/07/2015**	**27/08/2015**	**27/08/2015**	**27/08/2015**
			LW-9-5	LWE-1.03	LWE-1-5	LWE-1-0.3	LWE-1-5	FB-1-0.3	DUP-3 (Field Duplicate)	FB-1-5	FB-1-0.3	DUP-2 (Field Duplicate)	FB-1-5
General Chem													
Alkalinity (Total as CaCO3)	mg/L	1	98	92	93	96	95	110	110	93	97	100	97
Ammonia Nitrogen	mg/L	0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Unionized Ammonia, calculated	mg/L	0.0032	<0.00074	<0.0005	<0.0009	<0.00088	<0.00058	<0.0012	<0.0012	<0.00077	<0.0013	<0.0013	<0.00079
Biochemical Oxygen Demand, 5 Day	mg/L	2	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	2.0	<2.0	2.0	<2.0	<2.0
Chemical Oxygen Demand	mg/L	4	4.9	<4.0	<4.0	4.8	5	6.9	<4.0	<4.0	<4.0	<4.0	8.6
Conductivity	ms/cm	0.001	0.315	0.32	0.32	0.316	0.317	0.49	0.5	0.32	0.38	0.374	0.317
Conductivity, field measured	ms/cm		0.303	0.286	0.289	0.305	0.303	0.375	0.375	0.289	0.322	0.322	0.303
Hardness, Calcium Carbonate	mg/L	1	140	120	130	140	130	150	160	130	140	140	130
Temperature, field measured	C		7.69	11.95	7.28	12.2	8.84	12.04	12.04	7.59	13.63	13.63	9.53
Total Suspended Solids	mg/L	1	<10	<1	<1	<10	<10	5	6	<1	<10	<10	<10
pH	pH units		8.06	8.05	8	7.68	7.7	8.18	8.12	8.04	7.6	7.71	7.78
pH, field measured	pH units		7.99	7.61	8.09	7.91	7.84	8.06	8.06	8.01	8.04	8.04	7.95
Total Residual Chlorine, field measured	mg/L	0.0012	<0.0012	<0.0012	<0.0012	<0.0012	<0.0012	<0.0012	<0.0012	<0.0012	<0.0012	<0.0012	<0.0012
Metals/Metalloids													
Aluminum	mg/L	0.005	0.0053	0.0061	0.0063	0.007	0.0062	0.022	0.014	0.0079	0.033	0.013	<0.0050
Aluminum, filtered	mg/L	0.005	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Antimony	mg/L	0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Arsenic	mg/L	0.001	<0.0010	<0.0010	0.001	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	0.0011	<0.0010	<0.0010
Barium	mg/L	0.002	0.022	0.022	0.022	0.022	0.022	0.022	0.023	0.022	0.022	0.024	0.022
Beryllium	mg/L	0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Bismuth	mg/L	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Boron	mg/L	0.01	0.028	0.025	0.025	0.025	0.025	0.025	0.026	0.024	0.028	0.025	0.026
Cadmium	mg/L	0.0001	<0.000005	0.000013	<0.000010	<0.000005	<0.000005	<0.000010	<0.000010	<0.000010	0.000005	<0.000005	<0.000005
Calcium	mg/L	0.2	33	35	34	34	33	34	35	33	37	35	35
Chromium	mg/L	0.005	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Cobalt	mg/L	0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Copper	mg/L	0.001	<0.0010	0.0024	0.0088	0.0012	0.0011	<0.0010	<0.0010	0.0013	<0.0010	<0.0010	<0.0010
Lead	mg/L	0.1	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Lithium	mg/L	0.0005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Magnesium	mg/L	0.005	8.2	9	8.6	8.5	8.7	8.6	8.6	8.4	8.8	9	8.8
Manganese	mg/L	0.05	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	0.0035	0.003	<0.0020	0.017	0.0057	<0.0020
Mercury	mg/L	0.0001	<0.00001	<0.0001	<0.0001	<0.00001	<0.00001	<0.0001	<0.0001	<0.0001	<0.00001	<0.00001	<0.00001
Molybdenum	mg/L	0.002	0.0012	0.0014	0.0013	0.0011	0.0011	0.0011	0.0012	0.0012	0.0013	0.0013	0.0012
Nickel	mg/L	0.0005	0.0015	<0.0010	0.0014	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Potassium	mg/L	0.001	1.5	1.7	1.6	1.6	1.6	1.6	1.6	1.5	1.7	1.6	1.6
Selenium	mg/L	0.2	0.000128	0.00013	0.0002	0.000142	0.000117	0.00012	0.00018	0.00016	0.000133	0.000117	0.000146
Silicon	mg/L	0.05	0.29	0.3	0.34	0.34	0.34	0.33	0.35	0.37	0.66	0.29	0.4
Silver	mg/L	0.002	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Sodium	mg/L	0.0001	13	14	14	14	14	16	17	14	23	17	14
Strontium	mg/L	0.1	0.17	0.18	0.18	0.17	0.18	0.18	0.18	0.17	0.19	0.18	0.18
Tellurium	mg/L	0.001	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Thallium	mg/L	0.001	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050
Tin	mg/L	0.00005	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Titanium	mg/L	0.001	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Tungsten	mg/L	0.005	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Uranium	mg/L	0.001	0.00034	0.00041	0.00039	0.00033	0.00034	0.00037	0.00039	0.00039	0.00034	0.00036	0.00034
Vanadium	mg/L	0.0001	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	0.00059	<0.0005	<0.0005
Zinc	mg/L	0.0005	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	0.0062	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Zirconium	mg/L	0.005	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Iron	mg/L	0.001	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
PetrHydroCarb													
Petroleum Hydrocarbons - F1 (C6-C10)-BTEX	mg/L	0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Petroleum Hydrocarbons - F1 (C6-C10)	mg/L	0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Petroleum Hydrocarbons - F2 (C10-C16)	mg/L	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Petroleum Hydrocarbons - F3 (C16-C34)	mg/L	0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Petroleum Hydrocarbons - F4 (C34-C50)	mg/L	0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Other													
Morpholine	mg/L	0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
Hydrazine	mg/L												
Radionuclides													
Tritium	Bq/L	4.4	<4.2	13.1	<4.5	9.4	<4.2	8.04	9.82	<4.5	<4.2	<4.2	<4.2
Carbon-14	Bq/L	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Cobal-60	Bq/L	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Cesium-134	Bq/L	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.3	<0.1	<0.1	<0.1	<0.1	<0.1
Cesium-137	Bq/L	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1

Table F.2: Frenchman's Bay Surface Water Data

Analyte	Unit	Detection Limit	LWC-1	LWC-1	LWC-1	LWC-1	LOCATION 1	LOCATION 1	LOCATION 2	LOCATION 3	PN-5-1
			22/07/2015	22/07/2015	27/08/2015	27/08/2015	23/07/2015	23/07/2015	23/07/2015	23/07/2015	23/07/2015
			LWC-1-0.3	LWC-1-5	LWC-1-0.3	LWC-1-5	LOC-1	DUP-5 (Field Duplicate)	LOC-2	LOC-3	PN-5-1
Sample Depth	m		0.3 - 0.3	5 - 5	0.3 - 0.3	5 - 5	0.3 - 0.3	0.3 - 0.3	0.3 - 0.3	0.3 - 0.3	1 - 1
General Chem											
Alkalinity (Total as CaCO3)	mg/L	1	91	92	93	96	150	150	120	120	120
Ammonia Nitrogen	mg/L	0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Unionized Ammonia, calculated	mg/L	0.0032	<0.0023	<0.0017	<0.0013	<0.0010	<0.0032	<0.0032	<0.0033	<0.0056	<0.0069
Biochemical Oxygen Demand, 5 Day	mg/L	2	3.0	<2.0	<2.0	<2.0	4	3	5	4	3
Chemical Oxygen Demand	mg/L	4	<4.0	9.6	<4.0	<4.0	15	9.6	12	12	10
Conductivity	ms/cm	0.001	0.31	0.31	0.316	0.318	0.85	0.86	0.57	0.57	0.54
Conductivity, field measured	ms/cm		0.226	0.204	0.302	0.302	0.774	0.774	0.496	0.532	0.495
Hardness, Calcium Carbonate	mg/L	1	120	120	130	140	200	210	170	160	150
Temperature, field measured	C		14.15	10.03	12.2	12.94	23.94	23.94	23.53	23.35	21.52
Total Suspended Solids	mg/L	1	<1.0	<1.0	<10.0	<10.0	20	20	11	17	10
Total Organic Carbon	mg/L	0.2	--	--	--	--	4.9	4.9	4.6	4.8	4.5
pH	pH units		7.97	8.13	7.73	7.78	8.08	8.12	8.18	8.06	8.23
pH, field measured	pH units		8.27	8.27	8.08	7.94	8.11	8.11	8.14	8.4	8.56
Total Residual Chlorine, field measured	mg/L	0.0012	<0.0012	<0.0012	<0.0012	<0.0012	<0.0012	<0.0012	<0.0012	<0.0012	<0.0012
Metals/Metalloids											
Aluminum	mg/L	0.005	0.01	0.0053	0.008	<0.0050	0.22	0.27	0.13	0.17	0.09
Aluminum, filtered	mg/L	0.005	0.021	<0.0050	<0.0050	<0.0050	0.006	0.006	0.006	0.005	<0.0050
Antimony	mg/L	0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Arsenic	mg/L	0.001	<0.0010	<0.0010	<0.0010	<0.0010	0.001	<0.0010	<0.0010	0.0011	0.001
Barium	mg/L	0.002	0.023	0.022	0.022	0.022	0.046	0.044	0.034	0.035	0.032
Beryllium	mg/L	0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Bismuth	mg/L	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Boron	mg/L	0.01	0.026	0.025	0.026	0.025	0.042	0.04	0.035	0.034	0.033
Cadmium	mg/L	0.0001	0.000014	0.000014	<0.000005	<0.000005	<0.000010	0.00001	<0.000010	<0.000010	<0.000010
Calcium	mg/L	0.2	35	34	34	33	64	63	49	48	46
Chromium	mg/L	0.005	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Cobalt	mg/L	0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Copper	mg/L	0.001	<0.0010	<0.0010	<0.0010	<0.0010	0.0017	0.0017	0.0015	0.0014	0.0014
Lead	mg/L	0.1	<0.0005	<0.0005	<0.0005	<0.0005	0.00081	0.00092	0.00052	0.00062	<0.0005
Lithium	mg/L	0.0005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Magnesium	mg/L	0.005	8.9	8.5	9.1	8.6	11	11	9.4	9.3	9.1
Manganese	mg/L	0.05	<0.0020	<0.0020	<0.0020	<0.0020	0.078	0.08	0.045	0.058	0.03
Mercury	mg/L	0.0001	**<0.0001**	**<0.0001**	0.00001	0.00001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Molybdenum	mg/L	0.002	0.0014	0.0014	0.0012	0.0012	0.001	0.0012	0.0011	0.0012	0.0011
Nickel	mg/L	0.0005	<0.0010	<0.0010	0.0011	<0.0010	0.001	0.0013	<0.0010	<0.0010	<0.0010
Potassium	mg/L	0.001	1.6	1.6	1.7	1.6	2.3	2.3	2	2.1	2
Selenium	mg/L	0.2	0.00017	0.00013	0.000129	0.000126	0.00011	0.00013	0.00014	0.00012	<0.0001
Silicon	mg/L	0.05	0.19	0.27	0.27	0.31	1.4	1.4	0.84	0.91	0.6
Silver	mg/L	0.002	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Sodium	mg/L	0.0001	14	14	16	14	91	89	54	53	48
Strontium	mg/L	0.1	0.18	0.18	0.18	0.18	0.28	0.28	0.23	0.23	0.22
Tellurium	mg/L	0.001	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Thallium	mg/L	0.001	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050
Tin	mg/L	0.00005	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Titanium	mg/L	0.001	<0.005	<0.005	<0.005	<0.005	0.011	0.013	0.0059	0.0082	0.006
Tungsten	mg/L	0.005	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Uranium	mg/L	0.001	0.00042	0.00037	0.00035	0.00033	0.00045	0.00045	0.00038	0.00037	0.00037
Vanadium	mg/L	0.0001	<0.0005	<0.0005	<0.0005	<0.0005	0.0013	0.0013	0.001	0.0012	0.00084
Zinc	mg/L	0.0005	<0.0050	<0.0050	<0.0050	<0.0050	0.0051	<0.0050	<0.0050	0.0074	<0.0050
Zirconium	mg/L	0.005	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Iron	mg/L	0.001	<0.1	<0.1	<0.1	<0.1	0.49	0.56	0.26	0.35	0.18
PetrHydroCarb											
Petroleum Hydrocarbons - F1 (C6-C10)-BTEX	mg/L	0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Petroleum Hydrocarbons - F1 (C6-C10)	mg/L	0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Petroleum Hydrocarbons - F2 (C10-C16)	mg/L	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Petroleum Hydrocarbons - F3 (C16-C34)	mg/L	0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Petroleum Hydrocarbons - F4 (C34-C50)	mg/L	0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Other											
Morpholine	mg/L	0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
Radionuclides											
Tritium	Bq/L	4.4	<4.5	<4.5	<4.2	<4.2	14.6	13.1	11.1	16.2	11.6
Carbon-14	Bq/L	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Cobal-60	Bq/L	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Cesium-134	Bq/L	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Cesium-137	Bq/L	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1

Table F.2: Frenchman's Bay Surface Water Data

Analyte	Unit	Detection Limit	PN-9-1	PN-10-1	PN-10-1
			23/07/2015	23/07/2015	23/07/2015
			PN-9-1	PN-10-1	DUP-4 (Field Duplicate)
Sample Depth	m		1 - 1	1 - 1	1 - 1
General Chem					
Alkalinity (Total as CaCO3)	mg/L	1	120	120	120
Ammonia Nitrogen	mg/L	0.05	<0.05	<0.05	<0.05
Unionized Ammonia, calculated	mg/L	0.0032	<0.0061	<0.0056	<0.0056
Biochemical Oxygen Demand, 5 Day	mg/L	2	3	<2.0	<2.0
Chemical Oxygen Demand	mg/L	4	11	11	7.4
Conductivity	ms/cm	0.001	0.55	0.55	0.56
Conductivity, field measured	ms/cm		0.518	0.515	0.515
Hardness, Calcium Carbonate	mg/L	1	150	160	150
Temperature, field measured	C		21.61	21.1	21.1
Total Suspended Solids	mg/L	1	10	9	5
Total Organic Carbon	mg/L	0.2	4.5	4.4	3
pH	pH units		8.26	8.21	8.22
pH, field measured	pH units		8.49	8.47	8.47
Total Residual Chlorine, field measured	mg/L	0.0012	<0.0012	<0.0012	<0.0012
Metals/Metalloids					
Aluminum	mg/L	0.005	0.093	0.1	0.05
Aluminum, filtered	mg/L	0.005	<0.0050	<0.0050	<0.0050
Antimony	mg/L	0.0005	<0.0005	<0.0005	<0.0005
Arsenic	mg/L	0.001	0.001	0.0011	<0.0010
Barium	mg/L	0.002	0.03	0.032	0.024
Beryllium	mg/L	0.0005	<0.0005	<0.0005	<0.0005
Bismuth	mg/L	0.001	<0.001	<0.001	<0.001
Boron	mg/L	0.01	0.033	0.034	0.027
Cadmium	mg/L	0.0001	<0.000010	0.00001	0.00001
Calcium	mg/L	0.2	47	47	36
Chromium	mg/L	0.005	<0.0050	<0.0050	<0.0050
Cobalt	mg/L	0.0005	<0.0005	<0.0005	<0.0005
Copper	mg/L	0.001	0.0018	0.0021	0.0019
Lead	mg/L	0.1	<0.0005	<0.0005	<0.0005
Lithium	mg/L	0.0005	<0.005	<0.005	<0.005
Magnesium	mg/L	0.005	9.2	9.4	8.6
Manganese	mg/L	0.05	0.031	0.031	0.011
Mercury	mg/L	0.0001	<0.0001	<0.0001	<0.0001
Molybdenum	mg/L	0.002	0.0012	0.0012	0.0013
Nickel	mg/L	0.0005	<0.0010	<0.0010	<0.0010
Potassium	mg/L	0.001	2	2	1.6
Selenium	mg/L	0.2	0.00013	0.00022	0.00013
Silicon	mg/L	0.05	0.6	0.61	0.45
Silver	mg/L	0.002	<0.0001	<0.0001	<0.0001
Sodium	mg/L	0.0001	48	49	24
Strontium	mg/L	0.1	0.22	0.22	0.19
Tellurium	mg/L	0.001	<0.0010	<0.0010	<0.0010
Thallium	mg/L	0.001	<0.000050	<0.000050	<0.000050
Tin	mg/L	0.00005	<0.0010	<0.0010	<0.0010
Titanium	mg/L	0.001	0.0055	0.0056	<0.0050
Tungsten	mg/L	0.005	<0.0010	<0.0010	<0.0010
Uranium	mg/L	0.001	0.00038	0.00039	0.00039
Vanadium	mg/L	0.0001	0.0009	0.0008	0.00055
Zinc	mg/L	0.0005	<0.0050	<0.0050	<0.0050
Zirconium	mg/L	0.005	<0.0010	<0.0010	<0.0010
Iron	mg/L	0.001	0.19	0.19	<0.1
PetrHydroCarb					
Petroleum Hydrocarbons - F1 (C6-C10)-BTEX	mg/L	0.025	<0.025	<0.025	<0.025
Petroleum Hydrocarbons - F1 (C6-C10)	mg/L	0.025	<0.025	<0.025	<0.025
Petroleum Hydrocarbons - F2 (C10-C16)	mg/L	0.1	<0.1	<0.1	<0.1
Petroleum Hydrocarbons - F3 (C16-C34)	mg/L	0.2	<0.2	<0.2	<0.2
Petroleum Hydrocarbons - F4 (C34-C50)	mg/L	0.2	<0.2	<0.2	<0.2
Other					
Morpholine	mg/L	0.004	<0.004	<0.004	<0.004
Radionuclides					
Tritium	Bq/L	4.4	14.8	12.3	13.5
Carbon-14	Bq/L	0.1	<0.1	<0.1	<0.1
Cobal-60	Bq/L	0.1	<0.1	<0.1	<0.1
Cesium-134	Bq/L	0.1	<0.1	<0.1	<0.1
Cesium-137	Bq/L	0.1	<0.1	<0.1	<0.1

Table F.3: Frenchman's Bay Sediment Data

Analyte	Unit	Detection Limit	LOCATION 1	LOCATION 2	LOCATION 3	F-4	FB-5	FB-6	FB-7	FB-8	FB-9	FB-9	FB-10	PN-1-1	PN-2-1	PN-2-1	PN-3-1	PN-4-1
			2015/07/24	2015/07/24	2015/07/24	2015/07/24	2015/07/24	2015/07/24	2015/07/24	2015/07/24	2015/07/24	2015/07/24	2015/07/24	2015/07/24	2015/07/24	2015/07/24	2015/07/24	2015/07/24
			LOC-1	LOC-2	LOC-3	F-4	FB-5	FB-6	FB-7	FB-8	FB-9	DUP-2 (Field Duplicate)	FB-10	PN-1-1	PN-2-1	DUP-1 (Field Duplicate)	PN-3-1	PN-4-1
Sample Depth	cm		0-5	0-5	0-5	0-5	0-5	0-5	0-5	0-5	0-5	0-5	0-5	0-5	0-5	0-5	0-5	0-5
General Chem																		
Total Organic Carbon	µg/g dw	500	12000	12000	81000	23000	68000	53000	64000	100000	71000	75000	34000	21000	56000	61000	38000	54000
Gravel	%		0.24	0.32	0.45	<0.10	0.45	<0.10	0.14	0.44	0.38	<0.10	<0.10	<0.10	0.31	<0.10	<0.10	<0.10
Sand	%		67	62	34	29	17	20	21	24	8.3	15	29	59	17	19	24	13
Silt	%		29	33	49	64	64	58	54	51	55	68	63	32	51	52	48	54
Clay	%		3.9	4.5	16	7.4	19	22	25	25	36	18	8.8	8.4	31	29	28	33
Moisture	%		24.9	40.7	72	43.9	68.5	73.6	43.5	80.9	74.4	73.7	54.4	52	72.3	75.7	66.7	76.1
Metals/Metalloids																		
Aluminum	µg/g dw	50	3700	3800	8200	6700	11000	11000	11000	8000	13000	12000	7200	5400	11000	11000	8700	12000
Antimony	µg/g dw	0.2	<0.20	0.24	0.66	0.43	1.00	0.57	0.74	0.58	0.73	0.75	0.58	<0.20	0.55	0.65	0.42	0.55
Arsenic	µg/g dw	1	1	1	3	2	4	4	4	3	3	3	2	3	5	5	4	5
Barium	µg/g dw	0.5	29	28	66	47	86	92	98	69	100	93	57	38	95	92	71	110
Beryllium	µg/g dw	0.2	<0.20	<0.20	0.43	0.35	0.54	0.51	0.54	0.40	0.58	0.56	0.37	0.27	0.52	0.51	0.43	0.55
Bismuth	µg/g dw	1	<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	<1.0	<1.0
Boron	µg/g dw	5	<5.0	<5.0	8	5	9	7	9	9	8	8	6	<5.0	9	9	7	9
Cadmium	µg/g dw	0.1	<0.10	0.10	0.34	0.31	0.61	0.57	0.60	0.39	0.54	0.47	0.40	0.31	0.71	0.72	0.49	0.66
Calcium	µg/g dw	50	45000	48000	61000	74000	81000	100000	120000	70000	98000	91000	76000	89000	120000	110000	98000	130000
Chromium	µg/g dw	1	10	10	19	19	29	26	27	19	28	26	23	13	27	28	23	31
Cobalt	µg/g dw	0.1	3	3	6	6	8	8	8	5	8	7	6	5	8	8	7	8
Copper	µg/g dw	0.5	11	10	41	29	52	44	47	50	54	49	37	26	63	63	45	65
Iron	µg/g dw	50	7700	8100	14000	13000	19000	19000	20000	15000	21000	20000	14000	11000	20000	20000	16000	21000
Lead	µg/g dw	1	9	8	28	20	41	36	38	27	37	34	26	16	40	41	28	42
Magnesium	µg/g dw	50	3600	3800	5600	6900	8000	7300	7700	6100	8200	7900	6900	6800	8800	8700	8400	9600
Manganese	µg/g dw	1	160	170	400	310	480	510	540	410	570	540	370	300	590	590	480	660
Mercury	µg/g dw	0.05	<0.05	<0.05	<0.05	<0.05	0.06	0.05	0.06	<0.05	0.05	0.06	<0.05	<0.05	0.08	0.08	0.08	0.08
Molybdenum	µg/g dw	0.5	<0.50	<0.50	<0.50	<0.50	0.68	<0.50	0.55	0.51	0.60	0.52	<0.50	<0.50	0.51	0.55	<0.50	0.61
Nickel	µg/g dw	0.5	6	6	14	13	20	18	19	14	21	19	14	12	21	22	17	23
Phosphorus	µg/g dw	50	730	790	990	860	1000	1000	1000	920	1200	1100	890	740	1000	1100	910	1100
Potassium	µg/g dw	200	510	460	1100	900	1500	1400	1500	1100	1500	1500	990	890	1700	1700	1400	1900
Selenium	µg/g dw	0.5	<0.50	<0.50	0.78	<0.50	0.80	0.83	0.94	0.76	0.91	0.80	<0.50	<0.50	1.00	1.10	0.73	0.98
Silver	µg/g dw	0.2	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	0.21	0.21	<0.20	0.22
Sodium	µg/g dw	50	150	180	450	250	530	450	490	590	590	530	310	210	390	480	330	450
Strontium	µg/g dw	1	74	78	110	120	150	170	200	130	170	150	120	150	200	190	170	220
Thallium	µg/g dw	0.05	0.06	0.06	0.17	0.15	0.23	0.22	0.25	0.14	0.20	0.23	0.16	0.16	0.26	0.23	0.21	0.24
Tin	µg/g dw	5	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Uranium	µg/g dw	0.05	0.29	0.33	0.51	0.39	0.50	0.49	0.50	0.58	0.52	0.50	0.41	0.42	0.59	0.52	0.49	0.55
Vanadium	µg/g dw	5	12	13	21	19	27	26	28	20	26	26	20	16	27	28	23	28
Zinc	µg/g dw	5	58	57	160	130	230	190	190	170	230	220	180	83	220	200	140	230
Radionuclides																		
Carbon-14	Bq/kg-C dw	100	124	177	176	156	194	195	272	224	231	201	194	155	231	193	160	208
Cobal-60	Bq/kg dw	1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Cesium-134	Bq/kg dw	3.3	<3.3	<3.3	<3.3	<3.3	<3.3	<3.3	<3.3	<3.3	<3.3	<3.3	<3.3	<3.3	<3.3	<3.3	<3.3	<3.3
Cesium-137	Bq/kg dw	1	<1	<1	<1	1.4	1.71	1.58	2.05	1.2	1.65	1.58	1.38	2.68	2.86	2.84	2.96	2.43

Table F.3: Frenchman's Bay Sediment Data

Analyte	Unit	Detection Limit	PN-5-1	PN-6-1	PN-7-1	PN-8-1	PN-9-1	PN-10-1
			2015/07/24	2015/07/24	2015/07/24	2015/07/24	2015/07/24	2015/07/24
			PN-5-1	PN-6-1	PN-7-1	PN-8-1	PN-9-1	PN-10-1
Sample Depth	cm		0-5	0-5	0-5	0-5	0-5	0-5
General Chem								
Total Organic Carbon	µg/g dw	500	49000	51000	29000	20000	54000	74000
Gravel	%		<0.10	<0.10	0.11	0.4	<0.10	0.3
Sand	%		9.8	24	45	58	23	28
Silt	%		51	57	40	32	53	48
Clay	%		39	19	15	8.8	24	24
Moisture	%		75.6	71.2	59.3	51.3	71.4	74.9
Metals/Metalloids								
Aluminum	µg/g dw	50	12000	7400	6800	5700	9900	9500
Antimony	µg/g dw	0.2	0.57	0.36	0.32	0.28	0.58	0.56
Arsenic	µg/g dw	1	4	3	3	3	4	5
Barium	µg/g dw	0.5	98	62	53	43	81	82
Beryllium	µg/g dw	0.2	0.55	0.40	0.35	0.27	0.47	0.51
Bismuth	µg/g dw	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Boron	µg/g dw	5	8	6	7	6	10	25
Cadmium	µg/g dw	0.1	0.62	0.51	0.49	0.34	0.63	0.75
Calcium	µg/g dw	50	120000	96000	94000	98000	90000	87000
Chromium	µg/g dw	1	28	20	18	14	26	26
Cobalt	µg/g dw	0.1	8	6	6	5	7	7
Copper	µg/g dw	0.5	60	44	41	29	63	74
Iron	µg/g dw	50	20000	15000	14000	12000	17000	18000
Lead	µg/g dw	1	37	27	22	17	38	43
Magnesium	µg/g dw	50	8300	8700	8300	7200	8300	8500
Manganese	µg/g dw	1	560	390	380	320	480	440
Mercury	µg/g dw	0.05	0.07	0.05	0.05	<0.05	0.07	0.07
Molybdenum	µg/g dw	0.5	0.61	0.53	<0.50	<0.50	0.67	0.89
Nickel	µg/g dw	0.5	21	16	15	12	19	20
Phosphorus	µg/g dw	50	1000	920	960	840	1100	1500
Potassium	µg/g dw	200	1900	1100	1100	910	1400	1300
Selenium	µg/g dw	0.5	1.00	0.56	0.64	<0.50	0.90	1.10
Silver	µg/g dw	0.2	0.23	<0.20	<0.20	<0.20	0.20	0.25
Sodium	µg/g dw	50	370	310	230	210	410	450
Strontium	µg/g dw	1	190	160	160	160	160	160
Thallium	µg/g dw	0.05	0.21	0.19	0.19	0.19	0.23	0.26
Tin	µg/g dw	5	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Uranium	µg/g dw	0.05	0.55	0.49	0.52	0.43	0.51	0.68
Vanadium	µg/g dw	5	29	21	19	17	23	25
Zinc	µg/g dw	5	180	120	130	92	190	220
Radionuclides								
Carbon-14	Bq/kg-C dw	100	138	111	100	104	226	220
Cobal-60	Bq/kg dw	1	<1	<1	<1	<1	<1	<1
Cesium-134	Bq/kg dw	3.3	<3.3	<3.3	<3.3	<3.3	<3.3	<3.3
Cesium-137	Bq/kg dw	1	2.91	1.86	2.42	3.12	3.16	2.8

Table F.4: Stormwater Data - PN U1-4 Outfall

		Catchment 2				Catchment 1			
Station ID		**MH137**				**MH149**			
Sample 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
General	**Unit**								
Chloride	mg/L	25	25	27	24	650	110	790	150
Conductivity	mS/cm	0.31	0.301	0.323	0.29	2.32	0.521	2.99	0.714
Hardness, Calcium Carbonate	mg/L	120	120	130	120	260	93	430	98
pH	pH units	7.97	8.03	8.12	8.01	7.72	7.81	8.11	7.66
Phosphorous	mg/L	0.026	0.059	0.025	0.023	0.069	0.044	0.029	0.11
Total Suspended Solids	mg/L	< 10	46	< 10	<10	57	17	< 10	70
Toxicity									
% Mortality of Daphnia Magna in 100% Effluent Treatment	%	0	0	0	0	0	0	0	0
% Mortality of Rainbow Trout in 100% Effluent Treatment	%	0	0	0	0	0	0	0	0
Metals									
Aluminum	ug/L	67	300	110	19	680	350	57	1400
Antimony	ug/L	< 0.50	< 0.50	< 0.50	<0.50	1	< 0.50	0.59	0.56
Arsenic	ug/L	< 1.0	< 1.0	< 1.0	<1.0	< 1.0	< 1.0	< 1.0	<1.0
Barium	ug/L	26	28	26	22	64	19	67	31
Beryllium	ug/L	< 0.50	< 0.50	< 0.50	<0.50	< 0.50	< 0.50	< 0.50	<0.50
Bismuth	ug/L	< 1.0	< 1.0	< 1.0	<1.0	< 1.0	< 1.0	< 1.0	1.2
Boron	ug/L	26	19	24	15	32	11	19	<10
Cadmium	ug/L	< 0.10	< 0.10	< 0.10	<0.10	< 0.10	< 0.10	< 0.10	<0.10
Calcium	ug/L	35000	38000	38000	32000	96000	29000	140000	48000
Chromium	ug/L	< 5.0	< 5.0	< 5.0	<5.0	< 5.0	< 5.0	< 5.0	<5.0
Cobalt	ug/L	< 0.50	< 0.50	< 0.50	<0.50	0.65	< 0.50	< 0.50	1
Copper	ug/L	3.7	5.7	3.7	1.9	7.3	6.5	3.7	8.6
Iron	ug/L	110	570	200	<100	1200	450	130	1800
Lead	ug/L	< 0.50	1.1	< 0.50	<0.50	2.7	1.5	< 0.50	5.2
Lithium	ug/L	< 5.0	< 5.0	< 5.0	<5.0	< 5.0	< 5.0	< 5.0	<5.0
Magnesium	ug/L	8900	8400	8700	8100	13000	3500	20000	5200
Manganese	ug/L	13	37	9.3	2.8	110	59	16	120
Mercury (filtered)	ug/L	< 0.01	< 0.01	< 0.01	<0.01	< 0.01	< 0.01	< 0.01	<0.01
Molybdenum	ug/L	1.2	0.96	1.2	1.1	1.3	< 0.50	1.2	0.64
Nickel	ug/L	< 1.0	1.3	< 1.0	<1.0	2.5	< 1.0	< 1.0	2.6
Potassium	ug/L	1700	1600	1700	1600	2200	1100	2400	1900
Selenium	ug/L	< 2.0	< 2.0	< 2.0	<2.0	< 2.0	< 2.0	< 2.0	<2.0
Silicon	ug/L	240	810	530	370	2900	1300	2800	3400
Silver	ug/L	< 0.10	< 0.10	< 0.10	<0.10	< 0.10	< 0.10	< 0.10	<0.10
Sodium	ug/L	15000	14000	16000	14000	380000	63000	430000	99000
Strontium	ug/L	180	170	190	170	680	190	890	300
Tellurium	ug/L	< 1.0	< 1.0	< 1.0	<1.0	< 1.0	< 1.0	< 1.0	<1.0
Thallium	ug/L	< 0.050	< 0.050	< 0.050	<0.050	< 0.050	< 0.050	< 0.050	0.053
Tin	ug/L	< 1.0	< 1.0	< 1.0	<1.0	< 1.0	< 1.0	< 1.0	<1.0
Titanium	ug/L	< 5.0	16	7.1	<5.0	30	11	< 5.0	49
Tungsten	ug/L	< 1.0	< 1.0	< 1.0	<1.0	< 1.0	< 1.0	< 1.0	<1.0
Uranium	ug/L	0.89	0.46	0.62	0.45	0.3	0.33	0.58	0.37
Vanadium	ug/L	0.53	1.1	< 0.50	<0.50	2.9	1.2	< 0.50	3.6
Zinc	ug/L	< 5.0	20	12	<5.0	83	43	39	84
Zirconium	ug/L	< 1.0	< 1.0	< 1.0	<1.0	< 1.0	< 1.0	< 1.0	1.1
Petroleum Hydrocarbons (and BTEX)									
Benzene	ug/L	< 0.20	< 0.20	< 0.20	<0.20	< 0.20	< 0.20	< 0.20	<0.20
Toluene	ug/L	0.22	< 0.20	< 0.20	<0.20	< 0.20	< 0.20	< 0.20	<0.20
Ethylbenzene	ug/L	< 0.20	< 0.20	< 0.20	<0.20	< 0.20	< 0.20	< 0.20	<0.20
o-Xylene	ug/L	< 0.20	< 0.20	< 0.20	<0.20	< 0.20	< 0.20	< 0.20	<0.20
m,p-Xylenes	ug/L	< 0.40	< 0.40	< 0.40	<0.40	< 0.40	< 0.40	< 0.40	<0.40
Xylenes, Total	ug/L	< 0.40	< 0.40	< 0.40	<0.40	< 0.40	< 0.40	< 0.40	<0.40
Petroleum Hydrocarbons - F1 (C6-C10)-BTEX	ug/L	< 25	< 25	< 25	<25	< 25	< 25	< 25	<25
Petroleum Hydrocarbons - F1 (C6-C10)	ug/L	< 25	< 25	< 25	<25	< 25	< 25	< 25	<25
Petroleum Hydrocarbons - F2 (C10-C16)	ug/L	< 100	< 100	< 100	<100	< 100	< 100	< 100	<100
Petroleum Hydrocarbons - F3 (C16-C34)	ug/L	< 200	< 200	< 200	<200	< 200	< 200	< 200	<200
Petroleum Hydrocarbons - F4 (C34-C50)	ug/L	< 200	< 200	< 200	<200	< 200	< 200	< 200	<200
Reached Baseline at C50	ug/L	YES	YES	YES	YES	YES	YES	YES	YES
Radiological									
Carbon-14	Bq/L	< 20	< 20	< 20	<20	< 20	< 20	< 20	<20
Cesium-134	Bq/L	< 1	< 1	< 1	<1	< 1	< 1	< 1	<1
Cesium-137	Bq/L	< 1	< 1	< 1	<1	< 1	< 1	< 1	<1
Cobalt-60	Bq/L	-	< 1	< 1	<1	-	< 1	< 1	<1
Tritium (HTO)	Bq/L	21	588	145	163	327	141	882	235

Table F.5: Stormwater Data - PN U5-8 Outfall

		Catchment 8					Catchment 6			
Station ID		M3-3					MH15			
Sample Date		20-Aug-15	19-Nov-15	28-Oct-15	11-Jun-16		20-Aug-15	28-Oct-15	19-Nov-15	11-Jun-16
General	Unit					Dup of M3-3				
Chloride	mg/L	650	340	120	200	200	47	40	38	14
Conductivity	mS/cm	2.36	1.4	0.541	0.922	0.944	0.276	0.35	0.305	0.12
Hardness, Calcium Carbonate	mg/L	160	120	69	90	90	49	99	86	30
pH	pH units	7.91	7.83	7.77	7.91	7.87	7.47	7.85	7.84	7.8
Phosphorous	mg/L	0.029	0.025	0.037	0.05	0.052	0.54	0.16	0.27	0.13
Total Suspended Solids	mg/L	< 10	< 10	13	47	34	19	16	66	15
Toxicity										
% Mortality of Daphnia Magna in 100% Effluent Treatment	%	0	0	0	0	-	0	0	0	0
% Mortality of Rainbow Trout in 100% Effluent Treatment	%	0	0	0	0	-	0	0	0	0
Metals										
Aluminum	ug/L	110	79	460	390	370	270	210	1300	440
Antimony	ug/L	0.56	0.52	0.51	0.95	0.91	0.64	0.84	< 0.50	0.93
Arsenic	ug/L	< 1.0	< 1.0	< 1.0	1.4	1.5	< 1.0	< 1.0	< 1.0	<1.0
Barium	ug/L	37	21	12	20	20	14	24	25	8.5
Beryllium	ug/L	< 0.50	< 0.50	< 0.50	<0.50	<0.50	< 0.50	< 0.50	< 0.50	<0.50
Bismuth	ug/L	< 1.0	< 1.0	< 1.0	<1.0	<1.0	< 1.0	< 1.0	< 1.0	<1.0
Boron	ug/L	45	14	< 10	13	12	16	17	12	<10
Cadmium	ug/L	< 0.10	< 0.10	< 0.10	0.2	0.23	< 0.10	< 0.10	< 0.10	<0.10
Calcium	ug/L	52000	38000	21000	39000	38000	19000	27000	36000	14000
Chromium	ug/L	< 5.0	< 5.0	< 5.0	5.1	<5.0	< 5.0	< 5.0	< 5.0	<5.0
Cobalt	ug/L	< 0.50	< 0.50	< 0.50	0.97	0.95	< 0.50	< 0.50	0.88	<0.50
Copper	ug/L	6.2	3.6	5	12	11	11	7.1	7.4	7.5
Iron	ug/L	370	130	550	710	660	340	280	1600	510
Lead	ug/L	0.66	0.54	1.8	3.1	2.9	1.3	0.89	2.2	1.6
Lithium	ug/L	< 5.0	< 5.0	< 5.0	<5.0	<5.0	< 5.0	< 5.0	< 5.0	<5.0
Magnesium	ug/L	6800	5300	2000	3300	3200	2200	4800	4700	1000
Manganese	ug/L	96	20	33	60	60	27	20	63	24
Mercury (filtered)	ug/L	< 0.01	< 0.01	< 0.01	<0.01	0.01	< 0.01	< 0.01	0.02	<0.01
Molybdenum	ug/L	1.1	0.66	< 0.50	3.3	3.4	0.54	1.3	0.55	0.71
Nickel	ug/L	1.6	1	1.3	4.1	3.6	< 1.0	< 1.0	2.4	<1.0
Potassium	ug/L	1300	960	900	10000	9700	1200	1500	1200	1200
Selenium	ug/L	< 2.0	< 2.0	< 2.0	<2.0	<2.0	< 2.0	< 2.0	< 2.0	<2.0
Silicon	ug/L	1100	760	1100	2300	2200	1100	1500	3100	1100
Silver	ug/L	< 0.10	< 0.10	< 0.10	<0.10	<0.10	< 0.10	< 0.10	< 0.10	<0.10
Sodium	ug/L	420000	220000	77000	140000	130000	35000	31000	27000	9900
Strontium	ug/L	390	230	120	290	280	300	770	670	86
Tellurium	ug/L	< 1.0	< 1.0	< 1.0	<1.0	<1.0	< 1.0	< 1.0	< 1.0	<1.0
Thallium	ug/L	< 0.050	< 0.050	< 0.050	<0.050	<0.050	< 0.050	< 0.050	< 0.050	<0.050
Tin	ug/L	< 1.0	< 1.0	< 1.0	6.1	6.1	< 1.0	< 1.0	< 1.0	<1.0
Titanium	ug/L	6.3	5.4	16	16	16	18	7.9	44	23
Tungsten	ug/L	< 1.0	< 1.0	< 1.0	<1.0	<1.0	< 1.0	< 1.0	< 1.0	<1.0
Uranium	ug/L	0.16	0.24	< 0.10	0.21	0.22	< 0.10	0.32	0.17	0.13
Vanadium	ug/L	2.4	0.91	2.1	8.3	8.2	3.8	1.3	3.6	2.2
Zinc	ug/L	39	41	40	73	71	160	80	130	91
Zirconium	ug/L	< 1.0	< 1.0	< 1.0	<1.0	<1.0	< 1.0	< 1.0	< 1.0	<1.0
Petroleum Hydrocarbons (and BTEX)										
Benzene	ug/L	< 0.20	< 0.20	< 0.20	<0.20	<0.20	< 0.20	< 0.20	< 0.20	<0.20
Toluene	ug/L	0.31	< 0.20	< 0.20	<0.20	<0.20	< 0.20	< 0.20	< 0.20	<0.20
Ethylbenzene	ug/L	< 0.20	< 0.20	< 0.20	<0.20	<0.20	< 0.20	< 0.20	< 0.20	<0.20
o-Xylene	ug/L	< 0.20	< 0.20	< 0.20	<0.20	<0.20	< 0.20	< 0.20	0.38	<0.20
m,p-Xylenes	ug/L	< 0.40	< 0.40	< 0.40	<0.40	<0.40	< 0.40	< 0.40	0.46	<0.40
Xylenes, Total	ug/L	< 0.40	< 0.40	< 0.40	<0.40	<0.40	< 0.40	< 0.40	0.84	<0.40
Petroleum Hydrocarbons - F1 (C6-C10)-BTEX	ug/L	< 25	< 25	< 25	<25	<25	< 25	< 25	< 25	<25
Petroleum Hydrocarbons - F1 (C6-C10)	ug/L	< 25	< 25	< 25	<25	<25	< 25	< 25	< 25	<25
Petroleum Hydrocarbons - F2 (C10-C16)	ug/L	< 100	< 100	< 100	<100	<100	< 100	< 100	< 100	<100
Petroleum Hydrocarbons - F3 (C16-C34)	ug/L	< 200	< 200	< 200	<200	<200	< 200	< 200	< 200	<200
Petroleum Hydrocarbons - F4 (C34-C50)	ug/L	< 200	< 200	< 200	<200	<200	< 200	< 200	< 200	<200
Reached Baseline at C50	ug/L	YES	YES	YES	YES	YES	YES	YES	YES	YES
Radiological										
Carbon-14	Bq/L	< 20	< 20	< 20	<20	<20	< 20	< 20	< 20	<20
Cesium-134	Bq/L	< 1	< 1	< 1	<1	<1	< 1	< 1	< 1	<1
Cesium-137	Bq/L	< 1	< 1	< 1	<1	<1	< 1	< 1	< 1	<1
Cobalt-60	Bq/L	-	< 1	< 1	<1	<1	-	< 1	< 1	<1
Tritium (HTO)	Bq/L	974	145	50	78	79	182	1400	1110	1370

Table F.6: Stormwater Data - Lake Water East

		Concentration							
		Catchment 10				Catchment 13			
	Station ID	M2-1				M5-1			
	Unit	20-Aug-15	28-Oct-15	19-Nov-15	11-Jun-16	20-Aug-15	28-Oct-15	19-Nov-15	11-Jun-16
General									
Chloride	mg/L	600	110	890	180	320	16	340	92
Conductivity	mS/cm	2.2	0.539	3.38	0.814	1.36	0.135	1.59	0.455
Hardness, Calcium Carbonate	mg/L	150	81	330	76	130	41	190	63
pH	pH units	7.85	7.68	7.8	7.98	7.82	6.76	7.87	7.95
Phosphorous	mg/L	0.096	0.065	0.038	0.11	0.092	0.061	0.032	0.12
Total Suspended Solids	mg/L	72	46	20	110	< 10	25	< 10	82
Toxicity									
% Mortality of Daphnia Magna in 100% Effluent Treatment	%	0	0	0	0	0	0	0	0
% Mortality of Rainbow Trout in 100% Effluent Treatment	%	0	0	0	0	0	0	0	0
Metals									
Aluminum	ug/L	1800	990	740	1500	170	970	53	1600
Antimony	ug/L	0.84	1.4	0.64	0.61	0.51	0.62	< 0.50	0.88
Arsenic	ug/L	< 1.0	< 1.0	< 1.0	<1.0	< 1.0	< 1.0	< 1.0	<1.0
Barium	ug/L	50	20	73	35	29	9.3	32	41
Beryllium	ug/L	< 0.50	< 0.50	< 0.50	<0.50	< 0.50	< 0.50	< 0.50	<0.50
Bismuth	ug/L	< 1.0	< 1.0	< 1.0	<1.0	< 1.0	< 1.0	< 1.0	<1.0
Boron	ug/L	48	11	35	<10	41	< 10	43	13
Cadmium	ug/L	< 0.10	< 0.10	< 0.10	<0.10	< 0.10	< 0.10	< 0.10	<0.10
Calcium	ug/L	65000	34000	100000	66000	41000	16000	54000	47000
Chromium	ug/L	< 5.0	< 5.0	< 5.0	8.7	< 5.0	< 5.0	< 5.0	5.2
Cobalt	ug/L	1	< 0.50	0.57	1.2	< 0.50	< 0.50	< 0.50	1.1
Copper	ug/L	18	4.3	3.9	8	7.6	3.2	2.4	6.2
Iron	ug/L	1800	1200	760	3100	310	720	< 100	1900
Lead	ug/L	3.8	2.8	1.1	6.2	0.55	1.6	< 0.50	4
Lithium	ug/L	5.6	< 5.0	5.2	<5.0	< 5.0	< 5.0	< 5.0	5.1
Magnesium	ug/L	7200	3100	16000	4500	6100	1300	9400	3500
Manganese	ug/L	170	56	220	200	66	30	27	81
Mercury (filtered)	ug/L	< 0.01	< 0.01	< 0.01	<0.01	< 0.01	< 0.01	< 0.01	<0.01
Molybdenum	ug/L	1.8	0.56	1.9	0.8	1.2	< 0.50	1.8	0.58
Nickel	ug/L	3	1.8	1.5	4.2	1.4	1.6	< 1.0	3
Potassium	ug/L	3200	1700	3400	2300	2500	1100	2200	2400
Selenium	ug/L	< 2.0	< 2.0	< 2.0	<2.0	< 2.0	< 2.0	< 2.0	<2.0
Silicon	ug/L	5000	2300	3800	4400	1100	2000	930	7600
Silver	ug/L	< 0.10	< 0.10	< 0.10	<0.10	< 0.10	< 0.10	< 0.10	<0.10
Sodium	ug/L	400000	71000	540000	130000	220000	11000	250000	59000
Strontium	ug/L	400	160	680	230	660	110	1000	360
Tellurium	ug/L	< 1.0	< 1.0	< 1.0	<1.0	< 1.0	< 1.0	< 1.0	<1.0
Thallium	ug/L	< 0.050	< 0.050	< 0.050	<0.050	< 0.050	< 0.050	< 0.050	<0.050
Tin	ug/L	< 1.0	< 1.0	< 1.0	<1.0	< 1.0	< 1.0	< 1.0	<1.0
Titanium	ug/L	66	38	13	53	6.2	26	< 5.0	43
Tungsten	ug/L	< 1.0	< 1.0	< 1.0	<1.0	< 1.0	< 1.0	< 1.0	<1.0
Uranium	ug/L	0.3	0.19	0.78	0.27	0.17	< 0.10	0.64	0.6
Vanadium	ug/L	5.1	2.6	1.7	5	1	1.6	< 0.50	4.8
Zinc	ug/L	100	91	99	190	69	38	61	72
Zirconium	ug/L	1.2	< 1.0	< 1.0	1.1	< 1.0	< 1.0	< 1.0	2.7
Petroleum Hydrocarbons (and BTEX)									
Benzene	ug/L	< 0.20	< 0.20	< 0.20	<0.20	< 0.20	< 0.20	< 0.20	<0.20
Toluene	ug/L	0.44	< 0.20	< 0.20	<0.20	0.44	< 0.20	< 0.20	<0.20
Ethylbenzene	ug/L	< 0.20	< 0.20	< 0.20	<0.20	< 0.20	< 0.20	< 0.20	<0.20
o-Xylene	ug/L	< 0.20	< 0.20	< 0.20	<0.20	< 0.20	< 0.20	< 0.20	<0.20
m,p-Xylenes	ug/L	< 0.40	< 0.40	< 0.40	<0.40	< 0.40	< 0.40	< 0.40	<0.40
Xylenes, Total	ug/L	< 0.40	< 0.40	< 0.40	<0.40	< 0.40	< 0.40	< 0.40	<0.40
Petroleum Hydrocarbons - F1 (C6-C10)-BTEX	ug/L	< 25	< 25	< 25	<25	< 25	< 25	< 25	<25
Petroleum Hydrocarbons - F1 (C6-C10)	ug/L	< 25	< 25	< 25	<25	< 25	< 25	< 25	<25
Petroleum Hydrocarbons - F2 (C10-C16)	ug/L	< 100	< 100	< 100	<100	< 100	< 100	< 100	<100
Petroleum Hydrocarbons - F3 (C16-C34)	ug/L	< 200	< 200	< 200	<200	< 200	< 200	< 200	<200
Petroleum Hydrocarbons - F4 (C34-C50)	ug/L	< 200	< 200	< 200	<200	< 200	< 200	< 200	<200
Reached Baseline at C50	ug/L	YES	YES	YES	YES	YES	YES	YES	YES
Radiological									
Carbon-14	Bq/L	< 20	< 20	< 20	<20	< 20	< 20	< 20	<20
Cesium-134	Bq/L	< 1	< 1	< 1	<1	< 1	< 1	< 1	<1
Cesium-137	Bq/L	< 1	< 1	< 1	<1	< 1	< 1	< 1	<1
Cobalt-60	Bq/L	-	< 1	< 1	<1	-	< 1	< 1	<1
Tritium (Hydrogen-3)	Bq/L	227	41	222	53	158	< 15	111	<15

Table F.7: Stormwater Data - Lake Water West

		Concentration					
		Catchment 3					
	Station ID	MH211					
	Unit	20-Aug-15	28-Oct-15	19-Nov-15	20-Aug-15	11-Jun-16	
General							Dup of MH211
Chloride	mg/L	22	2.1	36	22	2.6	2.4
Conductivity	mS/cm	0.225	0.073	0.314	0.225	0.063	0.064
Hardness, Calcium Carbonate	mg/L	62	32	89	63	23	23
pH	pH units	7.6	7.66	7.92	7.55	7.49	7.56
Phosphorous	mg/L	0.16	0.06	0.083	0.16	0.11	0.11
Total Suspended Solids	mg/L	40	11	< 10	34	<10	<10
Toxicity							
% Mortality of Daphnia Magna in 100% Effluent Treatment	%	0	0	0	0	0	-
% Mortality of Rainbow Trout in 100% Effluent Treatment	%	0	0	0	0	30	-
Metals							
Aluminum	ug/L	550	160	130	570	120	100
Antimony	ug/L	3.7	0.9	1.5	3.6	0.76	0.94
Arsenic	ug/L	< 1.0	< 1.0	< 1.0	< 1.0	<1.0	<1.0
Barium	ug/L	24	8.4	26	23	4.8	4.2
Beryllium	ug/L	< 0.50	< 0.50	< 0.50	< 0.50	<0.50	<0.50
Bismuth	ug/L	< 1.0	< 1.0	< 1.0	< 1.0	<1.0	<1.0
Boron	ug/L	29	< 10	14	28	<10	<10
Cadmium	ug/L	0.69	0.23	0.15	0.87	0.21	0.2
Calcium	ug/L	27000	11000	32000	27000	8500	8600
Chromium	ug/L	< 5.0	< 5.0	< 5.0	< 5.0	<5.0	<5.0
Cobalt	ug/L	0.73	< 0.50	< 0.50	0.72	<0.50	<0.50
Copper	ug/L	43	12	11	42	7.6	6.9
Iron	ug/L	790	280	220	800	160	120
Lead	ug/L	4.9	2.2	1.1	5.1	1.3	1.3
Lithium	ug/L	< 5.0	< 5.0	< 5.0	< 5.0	<5.0	<5.0
Magnesium	ug/L	2200	690	2100	2300	520	480
Manganese	ug/L	42	15	20	41	11	11
Mercury (filtered)	ug/L	< 0.01	< 0.01	0.01	< 0.01	<0.01	<0.01
Molybdenum	ug/L	0.99	< 0.50	0.85	1	<0.50	<0.50
Nickel	ug/L	2.9	< 1.0	1	2.7	<1.0	<1.0
Potassium	ug/L	2200	750	1800	2200	1100	1100
Selenium	ug/L	< 2.0	< 2.0	< 2.0	< 2.0	<2.0	<2.0
Silicon	ug/L	2100	590	2000	2000	470	450
Silver	ug/L	< 0.10	< 0.10	< 0.10	0.17	<0.10	<0.10
Sodium	ug/L	20000	2000	29000	20000	2200	2200
Strontium	ug/L	110	30	120	110	24	24
Tellurium	ug/L	< 1.0	< 1.0	< 1.0	< 1.0	<1.0	<1.0
Thallium	ug/L	< 0.050	< 0.050	< 0.050	< 0.050	<0.050	<0.050
Tin	ug/L	< 1.0	< 1.0	< 1.0	< 1.0	<1.0	<1.0
Titanium	ug/L	18	6.8	5	17	6.5	<5.0
Tungsten	ug/L	< 1.0	< 1.0	< 1.0	< 1.0	<1.0	<1.0
Uranium	ug/L	0.13	< 0.10	0.34	0.14	0.1	<0.10
Vanadium	ug/L	2.8	1	1.2	2.9	0.88	0.71
Zinc	ug/L	510	220	150	510	160	160
Zirconium	ug/L	< 1.0	< 1.0	< 1.0	< 1.0	<1.0	<1.0
Petroleum Hydrocarbons (and BTEX)							
Benzene	ug/L	< 0.20	< 0.20	< 0.20	< 0.20	<0.20	<0.20
Toluene	ug/L	0.22	< 0.20	< 0.20	0.21	<0.20	<0.20
Ethylbenzene	ug/L	< 0.20	< 0.20	< 0.20	< 0.20	0.49	0.41
o-Xylene	ug/L	0.36	< 0.20	< 0.20	0.38	0.7	0.66
m,p-Xylenes	ug/L	0.56	< 0.40	< 0.40	0.55	1.5	1.6
Xylenes, Total	ug/L	0.92	< 0.40	< 0.40	0.94	2.2	2.3
Petroleum Hydrocarbons - F1 (C6-C10)-BTEX	ug/L	< 25	< 25	< 25	< 25	<25	<25
Petroleum Hydrocarbons - F1 (C6-C10)	ug/L	< 25	< 25	< 25	< 25	<25	<25
Petroleum Hydrocarbons - F2 (C10-C16)	ug/L	< 100	< 100	< 100	< 100	<100	<100
Petroleum Hydrocarbons - F3 (C16-C34)	ug/L	210	< 200	< 200	230	<200	<200
Petroleum Hydrocarbons - F4 (C34-C50)	ug/L	< 200	< 200	< 200	< 200	<200	<200
Reached Baseline at C50	ug/L	YES	YES	YES	YES	YES	YES
Radiological							
Carbon-14	Bq/L	< 20	< 20	< 20	< 20	<20	<20
Cesium-134	Bq/L	< 1	< 1	< 1	< 1	<1	<1
Cesium-137	Bq/L	< 1	< 1	< 1	< 1	<1	<1
Cobalt-60	Bq/L	-	< 1	< 1	-	<1	<1
Tritium (HTO)	Bq/L	3520	7080	39600	3480	2930	2930

Table F.8: Stormwater Data - Intake Channel

Station ID		CB70				MH106						MH20				MH85			
		20-Aug-15	28-Oct-15	19-Nov-15	11-Jun-16	20-Aug-15	28-Oct-15	19-Nov-15	20-Aug-15	11-Jun-16		20-Aug-15	28-Oct-15	19-Nov-15	11-Jun-16	20-Aug-15	28-Oct-15	19-Nov-15	11-Jun-16
General											Dup of MH106								
Chloride	mg/L	45	23	140	7.3	6.9	3	8	7.4	3.8	3.2	19	4.2	31	2.2	26	21	27	24
Conductivity	mS/cm	0.267	0.193	1.18	0.079	0.131	0.112	0.189	0.131	0.098	0.1	0.181	0.101	0.301	0.064	0.295	0.255	0.322	0.3
Hardness, Calcium Carbonate	mg/L	47	48	120	19	50	50	81	53	32	32	52	43	110	29	110	110	130	120
pH	pH units	7.84	7.64	7.27	7.68	7.75	7.78	7.86	7.78	7.65	7.66	7.58	7.64	7.85	7.53	8.16	7.95	8.08	8.05
Phosphorous	mg/L	0.13	0.055	3.7	0.098	0.14	0.077	0.069	0.14	0.069	0.067	0.16	0.072	0.075	0.078	0.035	0.064	0.049	0.023
Total Suspended Solids	mg/L	< 10	< 10	< 10	11	60	46	11	58	<10	<10	29	17	< 10	<10	< 10	27	15	<10
Toxicity																			
% Mortality of Daphnia Magna in 100% Effluent Treatment	%	0	0	100	0	0	0	0	0	0	-	0	0	0	0	0	0	0	0
% Mortality of Rainbow Trout in 100% Effluent Treatment	%	0	0	100	0	0	0	0	0	0	-	0	0	0	0	0	0	0	0
Metals																			
Aluminum	ug/L	190	160	320	240	650	370	320	600	110	84	420	200	290	160	110	500	170	16
Antimony	ug/L	8.7	2.6	1.6	1.2	2.6	1.5	1.4	2.6	2	2	2.4	0.88	0.9	0.8	0.71	< 0.50	< 0.50	<0.50
Arsenic	ug/L	< 1.0	< 1.0	9	<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	<1.0
Barium	ug/L	13	10	31	4.7	17	13	18	16	7.5	7.1	16	7.5	24	7	23	23	25	21
Beryllium	ug/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	< 0.50	<0.50	< 0.50	< 0.50	< 0.50	<0.50
Bismuth	ug/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	< 1.0	<1.0	< 1.0	< 1.0	< 1.0	<1.0
Boron	ug/L	27	12	49	<10	29	12	14	26	16	14	23	< 10	26	<10	23	16	27	15
Cadmium	ug/L	0.13	< 0.10	0.44	<0.10	0.19	0.18	0.22	0.15	0.15	0.15	0.24	0.16	< 0.10	0.15	< 0.10	< 0.10	< 0.10	<0.10
Calcium	ug/L	17000	15000	41000	8400	31000	26000	32000	29000	12000	12000	24000	15000	34000	12000	32000	35000	38000	34000
Chromium	ug/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	< 5.0	<5.0	< 5.0	< 5.0	< 5.0	<5.0
Cobalt	ug/L	< 0.50	< 0.50	1.8	<0.50	0.58	< 0.50	< 0.50	0.53	<0.50	<0.50	0.56	< 0.50	< 0.50	<0.50	< 0.50	< 0.50	< 0.50	<0.50
Copper	ug/L	20	3.8	23	6.9	21	7.2	13	17	9.7	9.4	17	8.5	7	13	23	7.4	5.4	2.6
Iron	ug/L	400	280	950	500	1000	710	480	970	110	<100	750	380	640	240	180	860	260	<100
Lead	ug/L	3	1.4	2.6	2.1	4.3	3.7	1.6	4	1.2	1.1	4.7	2.3	2.8	1.7	0.67	1.9	< 0.50	<0.50
Lithium	ug/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	< 5.0	<5.0	< 5.0	< 5.0	< 5.0	<5.0
Magnesium	ug/L	1600	1600	6500	440	1300	1100	1300	1300	440	430	1700	1100	6200	1200	8000	6900	8800	7900
Manganese	ug/L	20	26	180	25	51	39	26	48	10	9.8	37	24	45	18	11	45	15	3.2
Mercury (filtered)	ug/L	< 0.01	< 0.01	0.03	<0.01	< 0.01	< 0.01	< 0.01	< 0.01	<0.01	<0.01	< 0.01	< 0.01	< 0.01	<0.01	0.02	< 0.01	< 0.01	<0.01
Molybdenum	ug/L	0.9	0.91	1.9	<0.50	0.68	< 0.50	0.55	0.67	1	1	0.82	< 0.50	1.1	<0.50	1.1	0.85	1.2	1.1
Nickel	ug/L	1.4	< 1.0	7.2	1.1	2.4	1.6	1.9	2.7	1.1	1.3	1.7	1.1	1.9	<1.0	4.5	2.2	2.3	1.2
Potassium	ug/L	850	1300	31000	600	1400	1600	1400	1400	3800	3700	2900	1600	2400	1500	1600	1500	1700	1700
Selenium	ug/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	< 2.0	<2.0	< 2.0	< 2.0	< 2.0	<2.0
Silicon	ug/L	840	690	2000	690	1800	1200	1600	1700	810	760	1600	880	1300	720	330	1100	560	380
Silver	ug/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	< 0.10	<0.10	< 0.10	< 0.10	< 0.10	<0.10
Sodium	ug/L	36000	20000	110000	6400	6600	2800	6700	6300	3400	3400	14000	3200	19000	8300	16000	12000	15000	14000
Strontium	ug/L	200	120	570	47	90	61	87	87	58	58	110	41	170	42	180	140	180	170
Tellurium	ug/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	< 1.0	<1.0	< 1.0	< 1.0	< 1.0	<1.0
Thallium	ug/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	< 0.050	<0.050	< 0.050	< 0.050	< 0.050	<0.050
Tin	ug/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	< 1.0	<1.0	< 1.0	< 1.0	< 1.0	<1.0
Titanium	ug/L	9.6	5.9	20	12	23	15	14	20	<5.0	5	20	8.6	14	14	5.5	23	9.5	<5.0
Tungsten	ug/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	< 1.0	<1.0	< 1.0	< 1.0	< 1.0	<1.0
Uranium	ug/L	0.3	0.33	0.48	0.13	< 0.10	< 0.10	0.12	< 0.10	0.29	0.16	0.25	< 0.10	0.26	<0.10	0.55	0.31	0.4	0.5
Vanadium	ug/L	2.5	0.95	2.1	1.6	3.7	1.8	1.4	3.2	2.5	2.6	2.8	1.2	1.5	1.1	0.86	1.5	0.63	0.72
Zinc	ug/L	100	38	140	55	190	160	130	190	120	120	370	210	110	170	25	34	18	7.9
Zirconium	ug/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	< 1.0	<1.0	< 1.0	< 1.0	< 1.0	<1.0
Petroleum Hydrocarbons (and BTEX)																			
Benzene	ug/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	< 0.20	<0.20	< 0.20	< 0.20	< 0.20	<0.20
Toluene	ug/L	< 0.20	< 0.20	< 0.20	<0.20	0.38	< 0.20	< 0.20	0.3	0.26	0.22	< 0.20	< 0.20	< 0.20	0.35	0.23	< 0.20	< 0.20	<0.20
Ethylbenzene	ug/L	< 0.20	< 0.20	< 0.20	<0.20	0.69	0.39	< 0.20	0.46	1.1	1	< 0.20	< 0.20	< 0.20	1.1	< 0.20	< 0.20	< 0.20	<0.20
o-Xylene	ug/L	< 0.20	< 0.20	< 0.20	<0.20	2.7	2	< 0.20	2.4	3.8	3.6	< 0.20	< 0.20	< 0.20	1.2	< 0.20	< 0.20	< 0.20	<0.20
m,p-Xylenes	ug/L	< 0.40	< 0.40	< 0.40	<0.40	3	1.7	< 0.40	2.4	6.5	6.6	< 0.40	< 0.40	< 0.40	2.8	< 0.40	< 0.40	< 0.40	<0.40
Xylenes, Total	ug/L	< 0.40	< 0.40	< 0.40	<0.40	5.7	3.8	< 0.40	4.9	10	10	< 0.40	< 0.40	< 0.40	4.1	< 0.40	< 0.40	< 0.40	<0.40
Petroleum Hydrocarbons - F1 (C6-C10)-BTEX	ug/L	< 25	< 25	190	<25	< 25	< 25	< 25	< 25	<25	<25	< 25	< 25	< 25	<25	< 25	< 25	< 25	<25
Petroleum Hydrocarbons - F1 (C6-C10)	ug/L	< 25	< 25	190	<25	< 25	< 25	< 25	< 25	<25	<25	< 25	< 25	< 25	<25	< 25	< 25	< 25	<25
Petroleum Hydrocarbons - F2 (C10-C16)	ug/L	< 100	< 100	< 100	<100	< 100	< 100	< 100	< 100	<100	<100	< 100	< 100	< 100	<100	< 100	< 100	< 100	<100
Petroleum Hydrocarbons - F3 (C16-C34)	ug/L	< 200	< 200	< 200	<200	< 200	< 200	< 200	< 200	<200	<200	< 200	< 200	< 200	<200	< 200	< 200	< 200	<200
Petroleum Hydrocarbons - F4 (C34-C50)	ug/L	< 200	< 200	< 200	<200	< 200	< 200	< 200	< 200	<200	<200	< 200	< 200	< 200	<200	< 200	< 200	< 200	<200
Reached Baseline at C50	ug/L	YES	YES	YES	Yes	YES	YES	YES	YES	Yes	YES	YES	YES	YES	YES	YES	YES	YES	YES
Radiological	**Unit**																		
Carbon-14	Bq/L	< 20	< 20	< 20	<20	< 20	< 20	< 20	< 20	<20	<20	< 20	< 20	< 20	<20	< 20	< 20	< 20	<20
Cesium-134	Bq/L	< 1	< 1	< 1	<1	< 1	< 1	< 1	< 1	<1	<1	< 1	< 1	< 1	<1	< 1	< 1	< 1	<1
Cesium-137	Bq/L	< 1	< 1	< 1	<1	< 1	< 1	< 1	< 1	<1	<1	< 1	< 1	< 1	<1	< 1	< 1	< 1	<1
Cobalt-60	Bq/L	-	< 1	< 1	<1	-	< 1	< 1	-	<1	<1	-	< 1	< 1	<1	-	< 1	< 1	<1
Tritium (Hydrogen-3)	Bq/L	188	6450	11600	13800	1140	8560	14400	1150	1960	1950	2300	35300	19300	13700	4550	1690	1050	1190

Table F.9: Pickering Site Soil Data

Parameter	Unit	Detection Limit	GMS-26	GMS-26A	GMS-26B	GMS-28	GMS-28A	GMS-28B	GMS-31	GMS-31A	GMS-31B	GMS-31B	GMS-38	GMS-38	GMS-38A	GMS-38B	SITE 14 SS3	SITE 14 SS3A	SITE 14 SS3B
			GMS-26	GMS-26A	GMS-26B	GMS-28	GMS-28A	GMS-28B	GMS-31	GMS-31A	DUP 3	GMS-31B	DUP1	GMS-38	GMS-38A	GMS-38B	SITE 14 SS3	SITE 14 SS3A	DUP 2
Inorganics																			
Conductivity	ms/cm	0.002	0.24	-	-	0.09	-	-	0.14	-	-	-	0.51	0.56	-	-	0.38	-	-
Cyanide (free)	ug/g	0.01	0.02	-	-	0.33	-	-	< 0.01	-	-	-	0.01	0.01	-	-	0.22	-	-
Moisture, Percent	%	1	19	-	-	4.9	-	-	6.9	-	-	-	10	17	-	-	20	-	-
pH	pH units		7.35	-	-	7.72	-	-	7.67	-	-	-	7.73	7.47	-	-	7.58	-	-
Sodium Adsorption Ratio	-		0.2	-	-	0.3	-	-	0.28	-	-	-	4.7	5.2	-	-	4.6	-	-
Metals																			
Antimony	ug/g	0.2	< 0.20	< 0.20	< 0.20	2.9	0.88	< 0.20	< 0.20	< 0.20	1.3	< 0.20	< 0.20	0.2	< 0.20	0.23	5.6	1.3	< 0.20
Arsenic	ug/g	1	2.4	2	1.7	13	2	< 1.0	1.1	2.1	6.3	1.5	2.5	2.5	2.3	2.1	6.8	6.3	2
Barium	ug/g	0.5	130	110	110	94	29	17	23	95	23	52	130	140	130	88	18	20	54
Beryllium	ug/g	0.2	0.73	0.62	0.64	< 0.20	< 0.20	< 0.20	< 0.20	0.64	0.2	0.28	0.76	0.79	0.67	0.6	< 0.20	< 0.20	0.3
Boron	ug/g	5	6.3	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	5.2	< 5.0	6.9	< 5.0	5.4	6.6	5.9	6.8	< 5.0	5	5.7
Boron, Hot Water Soluble	ug/g	0.1	0.42	-	-	0.15	-	-	0.12	-	-	-	0.42	0.41	-	-	0.15	-	-
Cadmium	ug/g	1	0.28	0.17	0.29	0.43	< 0.10	< 0.10	< 0.10	0.14	0.31	< 0.10	0.19	0.2	0.28	0.15	0.2	0.17	< 0.10
Chromium	ug/g	0.1	26	23	23	13	7	5.8	7.2	22	15	12	27	28	26	27	13	16	13
Cobalt	ug/g	1	8.9	8.2	8.3	15	3.4	1.8	2.8	7	7.4	5.1	9.6	10	8.9	7.7	7.2	6.9	5.6
Copper	ug/g	0.5	18	16	17	190	16	4.8	6.3	16	83	12	19	27	19	18	78	69	13
Hexavalent Chromium	ug/g	0.2	< 0.2	-	-	< 0.2	-	-	< 0.2	-	-	-	< 0.2	< 0.2	-	-	< 0.2	-	-
Lead	ug/g	1	17	14	14	53	9.1	2.6	5.5	13	27	7.9	18	18	14	31	25	25	7.9
Mercury	ug/g	0.05	< 0.050	-	-	< 0.050	-	-	< 0.050	-	-	-	< 0.050	< 0.050	-	-	< 0.050	-	-
Molybdenum	ug/g	0.5	< 0.50	< 0.50	< 0.50	3.1	0.56	< 0.50	< 0.50	< 0.50	2.5	< 0.50	< 0.50	< 0.50	< 0.50	0.58	2.5	2.7	< 0.50
Nickel	ug/g	0.5	19	17	17	8.4	6.1	4.2	6.9	17	9.5	11	23	23	19	17	7.2	8	12
Selenium	ug/g	0.5	0.5	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50
Silver	ug/g	0.2	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20
Thallium	ug/g	0.05	0.19	0.16	0.19	0.06	0.09	< 0.050	0.064	0.17	0.081	0.12	0.19	0.22	0.19	0.17	< 0.050	< 0.050	0.13
Uranium	ug/g	0.05	0.82	0.6	0.66	0.37	0.35	0.29	0.36	0.89	0.38	0.52	0.66	0.75	0.71	0.6	0.34	0.34	0.52
Vanadium	ug/g	5	37	34	34	12	14	12	12	32	15	20	39	41	38	34	10	13	22
Zinc	ug/g	5	73	62	62	720	73	23	26	56	410	41	67	79	69	85	480	400	43
Petroleum Hydrocarbons																			
Benzene	ug/g	0.02	< 0.020			< 0.020			< 0.020				< 0.020	< 0.020			< 0.020		
Ethylbenzene	ug/g	0.02	< 0.020			< 0.020			< 0.020				< 0.020	< 0.020			< 0.020		
Toluene	ug/g	0.05	< 0.020			< 0.020			< 0.020				< 0.020	< 0.020			< 0.020		
Xylenes, Total	ug/g	0.02	< 0.020			< 0.020			< 0.020				< 0.020	< 0.020			< 0.020		
Petroleum Hydrocarbons - F1 (C6-C10)	ug/g	10	< 10			< 10			< 10				< 10	< 10			< 10		
Petroleum Hydrocarbons - F1 (C6-C10)-BTEX	ug/g	10	< 10			< 10			< 10				< 10	< 10			< 10		
Petroleum Hydrocarbons - F2 (C10-C16)	ug/g	10	< 10			< 10			< 10				< 10	< 10			< 10		
Petroleum Hydrocarbons - F3 (C16-C34)	ug/g	1000	< 50			< 50			< 50				< 50	< 50			110		
Petroleum Hydrocarbons - F4 (C34-C50)	ug/g	1000	< 50			< 50			< 50				< 50	< 50			150		
Petroleum Hydrocarbons - F4 Gravimetric	ug/g	1000	-			-			-				-	-			630		
Reached Baseline at C50	ug/g		YES			YES			YES				YES	YES			NO		

Table F.9: Pickering Site Soil Data

Parameter	Unit	SITE 14 SS3B	SITE 14 SS5	SITE 14 SS5A	SITE 14 SS5B	SITE 14 SS6	SITE 14 SS6A	SITE 14 SS6B	SITE 7 SS4	SITE 7 SS4A	SITE 7 SS4B
		SITE 14 SS3B	SITE 14 SS5	SITE 14 SS5A	SITE 14 SS5B	SITE 14 SS6	SITE 14 SS6A	SITE 14 SS6B	SITE 7 SS4	SITE 7 SS4A	SITE 7 SS4B
Inorganics											
Conductivity	ms/cm	-	1.2	-	-	0.82	-	-	0.68	-	-
Cyanide (free)	ug/g	-	0.33	-	-	0.03	-	-	< 0.01	-	-
Moisture, Percent	%	-	16	-	-	18	14	12	4.5	-	-
pH	pH units	-	7.56	-	-	7.4	-	-	8.07	-	-
Sodium Adsorption Ratio	-	-	11	-	-	5.4	-	-	11	-	-
Metals											
Antimony	ug/g	1.3	9.7	0.59	1.3	0.28	1.6	0.3	1	0.45	0.33
Arsenic	ug/g	5.6	58	2.4	8.5	1.2	6.8	1.1	4.2	1	1.6
Barium	ug/g	20	64	60	40	22	86	12	130	21	18
Beryllium	ug/g	< 0.20	0.22	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	0.26	< 0.20	< 0.20
Boron	ug/g	6	7.8	5.5	5	5.3	12	< 5.0	10	< 5.0	11
Boron, Hot Water Soluble	ug/g	-	0.37	-	-	0.36	-	-	0.38	-	-
Cadmium	ug/g	0.24	1.7	0.19	0.41	0.15	0.39	< 0.10	0.2	< 0.10	< 0.10
Chromium	ug/g	14	44	12	14	9.3	24	6.8	12	6.1	11
Cobalt	ug/g	6.8	67	3.5	9.9	2.2	8.7	2.1	4.9	1.9	2.4
Copper	ug/g	65	830	25	120	17	110	11	30	5.6	8.9
Hexavalent Chromium	ug/g	-	< 0.2	-	-	< 0.2	-	-	< 0.2	-	-
Lead	ug/g	21	230	15	36	9.9	38	7.1	21	4	11
Mercury	ug/g	-	< 0.050	-	-	< 0.050	-	-	< 0.050	-	-
Molybdenum	ug/g	1.8	16	1.2	3.2	< 0.50	2.2	< 0.50	1.1	< 0.50	< 0.50
Nickel	ug/g	8.5	20	6.8	7.3	5.7	13	4.2	9	4.2	7.5
Selenium	ug/g	< 0.50	2	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50
Silver	ug/g	< 0.20	0.53	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20
Thallium	ug/g	0.089	0.11	< 0.050	< 0.050	< 0.050	0.059	< 0.050	0.073	0.058	0.075
Uranium	ug/g	0.39	0.43	0.41	0.34	0.38	0.41	0.32	0.45	0.32	0.63
Vanadium	ug/g	15	14	14	11	15	13	11	7.9	13	6.6
Zinc	ug/g	310	3200	120	470	120	440	50	190	26	54
Petroleum Hydrocarbons											
Benzene	ug/g		< 0.020			< 0.020	-	-	< 0.020		
Ethylbenzene	ug/g		< 0.020			< 0.020	-	-	< 0.020		
Toluene	ug/g		< 0.020			< 0.020	-	-	< 0.020		
Xylenes, Total	ug/g		< 0.020			< 0.020	-	-	< 0.020		
Petroleum Hydrocarbons - F1 (C6-C10)	ug/g		< 10			< 10	< 10	< 10	< 10		
Petroleum Hydrocarbons - F1 (C6-C10)-BTEX	ug/g		< 10			< 10	< 10	< 10	< 10		
Petroleum Hydrocarbons - F2 (C10-C16)	ug/g		< 10			< 10	< 10	< 10	< 10		
Petroleum Hydrocarbons - F3 (C16-C34)	ug/g		1100			160	93	120	54		
Petroleum Hydrocarbons - F4 (C34-C50)	ug/g		1500			320	160	240	71		
Petroleum Hydrocarbons - F4 Gravimetric	ug/g		5700			1400	560	1100	400		
Reached Baseline at C50	ug/g		NO			NO	NO	NO	NO		

Table F.9: Pickering Site Soil Data

Parameter	Unit	Detection Limit	GMS-26	GMS-26A	GMS-26B	GMS-28	GMS-28A	GMS-28B	GMS-31	GMS-31A	GMS-31B	GMS-31B	GMS-38	GMS-38	GMS-38A	GMS-38B	SITE 14 SS3	SITE 14 SS3A	SITE 14 SS3B
			GMS-26	GMS-26A	GMS-26B	GMS-28	GMS-28A	GMS-28B	GMS-31	GMS-31A	DUP 3	GMS-31B	DUP1	GMS-38	GMS-38A	GMS-38B	SITE 14 SS3	SITE 14 SS3A	DUP 2
VOCs																			
1,1,1,2-Tetrachloroethane	ug/g	0.05	< 0.050			< 0.050			< 0.050				< 0.050	< 0.050			< 0.050		
1,1,1-Trichloroethane	ug/g	0.05	< 0.050			< 0.050			< 0.050				< 0.050	< 0.050			< 0.050		
1,1,2,2-Tetrachloroethane	ug/g	0.05	< 0.050			< 0.050			< 0.050				< 0.050	< 0.050			< 0.050		
1,1,2-Trichloroethane	ug/g	0.05	< 0.050			< 0.050			< 0.050				< 0.050	< 0.050			< 0.050		
1,1-Dichloroethane	ug/g	0.05	< 0.050			< 0.050			< 0.050				< 0.050	< 0.050			< 0.050		
1,1-Dichloroethene	ug/g	0.05	< 0.050			< 0.050			< 0.050				< 0.050	< 0.050			< 0.050		
1,2-Dibromoethane	ug/g	0.05	< 0.050			< 0.050			< 0.050				< 0.050	< 0.050			< 0.050		
1,2-Dichlorobenzene	ug/g	0.05	< 0.050			< 0.050			< 0.050				< 0.050	< 0.050			< 0.050		
1,2-Dichloroethane	ug/g	0.05	< 0.050			< 0.050			< 0.050				< 0.050	< 0.050			< 0.050		
1,2-Dichloropropane	ug/g	0.05	< 0.050			< 0.050			< 0.050				< 0.050	< 0.050			< 0.050		
1,3-Dichlorobenzene	ug/g	0.05	< 0.050			< 0.050			< 0.050				< 0.050	< 0.050			< 0.050		
1,3-Dichloropropene, Total	ug/g	0.05	< 0.050			< 0.050			< 0.050				< 0.050	< 0.050			< 0.050		
1,4-Dichlorobenzene	ug/g	0.05	< 0.050			< 0.050			< 0.050				< 0.050	< 0.050			< 0.050		
2-Butanone	ug/g	0.5	< 0.50			< 0.50			< 0.50				< 0.50	< 0.50			< 0.50		
4-Methyl-2-pentanone	ug/g	0.5	< 0.50			< 0.50			< 0.50				< 0.50	< 0.50			< 0.50		
Acetone	ug/g	0.5	< 0.50			< 0.50			< 0.50				< 0.50	< 0.50			< 0.50		
Benzene	ug/g	0.5	< 0.020			< 0.020			< 0.020				< 0.020	< 0.020			< 0.020		
Bromodichloromethane	ug/g	0.02	< 0.050			< 0.050			< 0.050				< 0.050	< 0.050			< 0.050		
Bromoform	ug/g	0.05	< 0.050			< 0.050			< 0.050				< 0.050	< 0.050			< 0.050		
Bromomethane	ug/g	0.05	< 0.050			< 0.050			< 0.050				< 0.050	< 0.050			< 0.050		
Carbon Tetrachloride	ug/g	0.05	< 0.050			< 0.050			< 0.050				< 0.050	< 0.050			< 0.050		
Chlorobenzene	ug/g	0.05	< 0.050			< 0.050			< 0.050				< 0.050	< 0.050			< 0.050		
Chloroform	ug/g	0.05	< 0.050			< 0.050			< 0.050				< 0.050	< 0.050			< 0.050		
cis-1,2-Dichloroethene	ug/g	0.05	< 0.050			< 0.050			< 0.050				< 0.050	< 0.050			< 0.050		
cis-1,3-Dichloropropene	ug/g	0.03	< 0.030			< 0.030			< 0.030				< 0.030	< 0.030			< 0.030		
Dibromochloromethane	ug/g	0.05	< 0.050			< 0.050			< 0.050				< 0.050	< 0.050			< 0.050		
Dichlorodifluoromethane	ug/g	0.05	< 0.050			< 0.050			< 0.050				< 0.050	< 0.050			< 0.050		
Ethylbenzene	ug/g	0.02	< 0.020			< 0.020			< 0.020				< 0.020	< 0.020			< 0.020		
Methyl tert-Butyl Ether	ug/g	0.05	< 0.050			< 0.050			< 0.050				< 0.050	< 0.050			< 0.050		
Methylene Chloride	ug/g	0.05	< 0.050			< 0.050			< 0.050				< 0.050	< 0.050			< 0.050		
n-Hexane	ug/g	0.05	< 0.050			< 0.050			< 0.050				< 0.050	< 0.050			< 0.050		
Styrene	ug/g	0.05	< 0.050			< 0.050			< 0.050				< 0.050	< 0.050			< 0.050		
Tetrachloroethene	ug/g	0.05	< 0.050			< 0.050			< 0.050				< 0.050	< 0.050			< 0.050		
Toluene	ug/g	0.02	< 0.020			< 0.020			< 0.020				< 0.020	< 0.020			< 0.020		
trans-1,2-Dichloroethene	ug/g	0.05	< 0.050			< 0.050			< 0.050				< 0.050	< 0.050			< 0.050		
trans-1,3-Dichloropropene	ug/g	0.04	< 0.040			< 0.040			< 0.040				< 0.040	< 0.040			< 0.040		
Trichloroethene	ug/g	0.05	< 0.050			< 0.050			< 0.050				< 0.050	< 0.050			< 0.050		
Trichlorofluoromethane	ug/g	0.05	< 0.050			< 0.050			< 0.050				< 0.050	< 0.050			< 0.050		
Vinyl Chloride	ug/g	0.02	< 0.020			< 0.020			< 0.020				< 0.020	< 0.020			< 0.020		
Xylenes, Total	ug/g	0.02	< 0.020			< 0.020			< 0.020				< 0.020	< 0.020			< 0.020		

Table F.9: Pickering Site Soil Data

Parameter	Unit	SITE 14 SS3B	SITE 14 SS5	SITE 14 SS5A	SITE 14 SS5B	SITE 14 SS6	SITE 14 SS6A	SITE 14 SS6B	SITE 7 SS4	SITE 7 SS4A	SITE 7 SS4B
		SITE 14 SS3B	SITE 14 SS5	SITE 14 SS5A	SITE 14 SS5B	SITE 14 SS6	SITE 14 SS6A	SITE 14 SS6B	SITE 7 SS4	SITE 7 SS4A	SITE 7 SS4B
VOCs											
1,1,1,2-Tetrachloroethane	ug/g		< 0.050			< 0.050			< 0.050		
1,1,1-Trichloroethane	ug/g		< 0.050			< 0.050			< 0.050		
1,1,2,2-Tetrachloroethane	ug/g		< 0.050			< 0.050			< 0.050		
1,1,2-Trichloroethane	ug/g		< 0.050			< 0.050			< 0.050		
1,1-Dichloroethane	ug/g		< 0.050			< 0.050			< 0.050		
1,1-Dichloroethene	ug/g		< 0.050			< 0.050			< 0.050		
1,2-Dibromoethane	ug/g		< 0.050			< 0.050			< 0.050		
1,2-Dichlorobenzene	ug/g		< 0.050			< 0.050			< 0.050		
1,2-Dichloroethane	ug/g		< 0.050			< 0.050			< 0.050		
1,2-Dichloropropane	ug/g		< 0.050			< 0.050			< 0.050		
1,3-Dichlorobenzene	ug/g		< 0.050			< 0.050			< 0.050		
1,3-Dichloropropene, Total	ug/g		< 0.050			< 0.050			< 0.050		
1,4-Dichlorobenzene	ug/g		< 0.050			< 0.050			< 0.050		
2-Butanone	ug/g		< 0.50			< 0.50			< 0.50		
4-Methyl-2-pentanone	ug/g		< 0.50			< 0.50			< 0.50		
Acetone	ug/g		< 0.50			< 0.50			< 0.50		
Benzene	ug/g		< 0.020			< 0.020			< 0.020		
Bromodichloromethane	ug/g		< 0.050			< 0.050			< 0.050		
Bromoform	ug/g		< 0.050			< 0.050			< 0.050		
Bromomethane	ug/g		< 0.050			< 0.050			< 0.050		
Carbon Tetrachloride	ug/g		< 0.050			< 0.050			< 0.050		
Chlorobenzene	ug/g		< 0.050			< 0.050			< 0.050		
Chloroform	ug/g		< 0.050			< 0.050			< 0.050		
cis-1,2-Dichloroethene	ug/g		< 0.050			< 0.050			< 0.050		
cis-1,3-Dichloropropene	ug/g		< 0.030			< 0.030			< 0.030		
Dibromochloromethane	ug/g		< 0.050			< 0.050			< 0.050		
Dichlorodifluoromethane	ug/g		< 0.050			< 0.050			< 0.050		
Ethylbenzene	ug/g		< 0.020			< 0.020			< 0.020		
Methyl tert-Butyl Ether	ug/g		< 0.050			< 0.050			< 0.050		
Methylene Chloride	ug/g		< 0.050			< 0.050			< 0.050		
n-Hexane	ug/g		< 0.050			< 0.050			< 0.050		
Styrene	ug/g		< 0.050			< 0.050			< 0.050		
Tetrachloroethene	ug/g		< 0.050			< 0.050			< 0.050		
Toluene	ug/g		< 0.020			< 0.020			< 0.020		
trans-1,2-Dichloroethene	ug/g		< 0.050			< 0.050			< 0.050		
trans-1,3-Dichloropropene	ug/g		< 0.040			< 0.040			< 0.040		
Trichloroethene	ug/g		< 0.050			< 0.050			< 0.050		
Trichlorofluoromethane	ug/g		< 0.050			< 0.050			< 0.050		
Vinyl Chloride	ug/g		< 0.020			< 0.020			< 0.020		
Xylenes, Total	ug/g		< 0.020			< 0.020			< 0.020		

Table F.9: Pickering Site Soil Data

Parameter	Unit	Detection Limit	GMS-26	GMS-26A	GMS-26B	GMS-28	GMS-28A	GMS-28B	GMS-31	GMS-31A	GMS-31B	GMS-31B	GMS-38	GMS-38	GMS-38A	GMS-38B	SITE 14 SS3	SITE 14 SS3A	SITE 14 SS3B
			GMS-26	GMS-26A	GMS-26B	GMS-28	GMS-28A	GMS-28B	GMS-31	GMS-31A	DUP 3	GMS-31B	DUP1	GMS-38	GMS-38A	GMS-38B	SITE 14 SS3	SITE 14 SS3A	DUP 2
Semi-VOCs																			
1- & 2-Methylnaphthalene	ug/g	0.0071	< 0.0071			0.013			0.012				< 0.0071	< 0.0071			< 0.0071		
1-Methylnaphthalene	ug/g	0.005	< 0.0050			0.0067			0.0059				< 0.0050	< 0.0050			< 0.0050		
2-Methylnaphthalene	ug/g	0.005	< 0.0050			0.0063			0.0061				< 0.0050	< 0.0050			< 0.0050		
4-Methyl-2-pentanone	ug/g	0.005	< 0.50			< 0.50			< 0.50				< 0.50	< 0.50			< 0.50		
Acenaphthene	ug/g	0.005	< 0.0050			< 0.0050			< 0.0050				< 0.0050	< 0.0050			< 0.0050		
Acenaphthylene	ug/g	0.005	< 0.0050			< 0.0050			< 0.0050				< 0.0050	< 0.0050			< 0.0050		
Anthracene	ug/g	0.005	< 0.0050			< 0.0050			< 0.0050				0.012	< 0.0050			< 0.0050		
Benzo [b,j] fluoranthene	ug/g	0.005	0.012			0.014			< 0.0050				0.076	0.018			0.014		
Benzo[a]anthracene	ug/g	0.005	0.0077			0.0077			< 0.0050				0.065	0.0083			0.0072		
Benzo[a]pyrene	ug/g	0.005	0.0075			0.0087			< 0.0050				0.052	0.01			0.0083		
Benzo[g,h,i]perylene	ug/g	0.005	0.0055			0.0093			< 0.0050				0.031	0.0099			0.012		
Benzo[k]fluoranthene	ug/g	0.005	< 0.0050			< 0.0050			< 0.0050				0.022	< 0.0050			< 0.0050		
Chrysene	ug/g	0.005	0.0072			0.011			< 0.0050				0.064	0.013			0.0088		
Dibenzo[a,h]anthracene	ug/g	0.005	< 0.0050			< 0.0050			< 0.0050				0.0066	< 0.0050			< 0.0050		
Fluoranthene	ug/g	0.005	0.016			0.019			< 0.0050				0.17	0.023			0.017		
Fluorene	ug/g	0.005	< 0.0050			< 0.0050			< 0.0050				< 0.0050	< 0.0050			< 0.0050		
Indeno[1,2,3-cd]pyrene	ug/g	0.005	0.0058			0.0072			< 0.0050				0.036	0.0097			0.0081		
Naphthalene	ug/g	0.005	< 0.0050			< 0.0050			< 0.0050				< 0.0050	< 0.0050			< 0.0050		
Phenanthrene	ug/g	0.005	< 0.0050			0.019			0.0072				0.068	0.0085			0.013		
Pyrene	ug/g	0.005	0.015			0.016			< 0.0050				0.12	0.018			0.014		
Styrene	ug/g	0.05	< 0.050			< 0.050			< 0.050				< 0.050	< 0.050			< 0.050		
Diethylene Glycol	mg/kg	10	< 10			< 10			< 10				< 10	< 10			< 10		
Ethylene Glycol	mg/kg	10	< 10			< 10			< 10				< 10	< 10			< 10		
Propylene Glycol	mg/kg	10	< 10			< 10			< 10				< 10	< 10			< 10		
Total Glycols	mg/kg	10	< 10			< 10			< 10				< 10	< 10			< 10		
Radionuclides																			
Carbon-14	Bq/kg		-			-			-				-				-		
Carbon-14	Bq/kg-C		557			<92			<92				465				<72		
Cobalt-60	Bq/kg		<1.00			<1.00			<1.00				<1.00				<1.00		
Cesium-134	Bq/kg		<1.00			<1.00			<1.00				<1.00				<1.00		
Cesium-137	Bq/kg		<1.00			<1.00			<1.00				<1.00				<1.00		
Potassium-40	Bq/kg		663			199			299				624				274		
Tritium	Bq/kg		92.4			11			<7.8				40.8				50		

Table F.9: Pickering Site Soil Data

Parameter	Unit	SITE 14 SS3B	SITE 14 SS5	SITE 14 SS5A	SITE 14 SS5B	SITE 14 SS6	SITE 14 SS6A	SITE 14 SS6B	SITE 7 SS4	SITE 7 SS4A	SITE 7 SS4B
		SITE 14 SS3B	SITE 14 SS5	SITE 14 SS5A	SITE 14 SS5B	SITE 14 SS6	SITE 14 SS6A	SITE 14 SS6B	SITE 7 SS4	SITE 7 SS4A	SITE 7 SS4B
Semi-VOCs											
1- & 2-Methylnaphthalene	ug/g		< 0.14			< 0.14			0.018		
1-Methylnaphthalene	ug/g		< 0.10			< 0.10			0.0094		
2-Methylnaphthalene	ug/g		< 0.10			< 0.10			0.0083		
4-Methyl-2-pentanone	ug/g		< 0.50			< 0.50			< 0.50		
Acenaphthene	ug/g		< 0.10			< 0.10			< 0.0050		
Acenaphthylene	ug/g		< 0.10			< 0.10			< 0.0050		
Anthracene	ug/g		< 0.10			< 0.10			< 0.0050		
Benzo [b,j] fluoranthene	ug/g		< 0.10			0.11			0.021		
Benzo[a]anthracene	ug/g		< 0.10			< 0.10			0.0086		
Benzo[a]pyrene	ug/g		< 0.10			< 0.10			0.013		
Benzo[g,h,i]perylene	ug/g		< 0.10			< 0.10			0.016		
Benzo[k]fluoranthene	ug/g		< 0.10			< 0.10			0.0057		
Chrysene	ug/g		< 0.10			< 0.10			0.013		
Dibenzo[a,h]anthracene	ug/g		< 0.10			< 0.10			< 0.0050		
Fluoranthene	ug/g		< 0.10			0.12			0.019		
Fluorene	ug/g		< 0.10			< 0.10			< 0.0050		
Indeno[1,2,3-cd]pyrene	ug/g		< 0.10			< 0.10			0.014		
Naphthalene	ug/g		< 0.10			< 0.10			< 0.0050		
Phenanthrene	ug/g		< 0.10			< 0.10			0.017		
Pyrene	ug/g		< 0.10			0.12			0.017		
Styrene	ug/g		< 0.050			< 0.050			< 0.050		
Diethylene Glycol	mg/kg		< 10			< 10			< 10		
Ethylene Glycol	mg/kg		< 10			< 10			< 10		
Propylene Glycol	mg/kg		< 10			< 10			< 10		
Total Glycols	mg/kg		< 10			< 10			< 10		
Radionuclides											
Carbon-14	Bq/kg		-			-	-		-		
Carbon-14	Bq/kg-C		118			156	<72		<77		
Cobalt-60	Bq/kg		<1.00			<1.00	<1.00		<1.00		
Cesium-134	Bq/kg		<1.00			<1.00	<1.00		<1.00		
Cesium-137	Bq/kg		<1.00			<1.00	<1.00		<1.00		
Potassium-40	Bq/kg		213			250	230		213		
Tritium	Bq/kg		36			18.1	15.2		13		

Appendix G Stormwater Runoff Calculations

G.1 Introduction

This appendix was presented in the 2017 ERA (Ecometrix and Golder, 2017) and has been included for informational purposes.

This appendix summarizes the approach used to model runoff flows reporting to two discharge locations at the PN site. The two discharge locations are M2-1 and M5-1, shown on the Figure G.1. These two catchments have been changed and therefore an assessment was considered necessary to assess flow resulting from rainfall. Other catchments in the area have not been altered since previous sampling. The calculations are used to assess the run-off into M5-1. Modelling was undertaken using the Environmental Protection Agency Storm Water Management Model 5.0 (SWMM5) hydrologic model, and verified for the M2-1 discharge location based on continuous flow measurements at M2-1 during three storm events in 2015 and one event in 2016.

G.2 Methodology

G.2.1 Catchment Delineation

Mapping information from the catchments contributing to the two discharge locations (M2-1 and M5-1) was used. Drawings show general drainage directions and culverts under internal roadways but do not show details of the storm sewer system in the catchments.
The drainage catchments contributing to M2-1 and M5-1 are shown on Figure G.1, with M2-1 showing a contributing area of 2 ha and M5-1 showing a contributing area of 4.5 ha.

G.2.2 Modelling Layout

Both M2-1 and M5-1 catchments were modelled in SWMM5 as single catchment. In this method, the modeled catchment was described as a single unit draining to a single outlet, rather than multiple catchments, catch basins, culverts, and pipes. This is considered acceptable for this level of estimation, as the catchments are both less than 5 ha and the stormwater management systems in each catchment are not expected to have a significant impact on losses. Neither of the two catchments appears to have significant runoff storage features (i.e., no stormwater ponds), and therefore only minimal storage effects on the peak flows are expected. Both catchments were assumed to have a surface slope of 1% consistent with parking lot grading.

Based on mapping, knowledge of the area, Google Earth imagery and typical literature values assumptions were made related to the surface conditions. The catchment M2-1 was assumed to be 25% impervious and 75% pervious (assuming gravel parking areas), while the catchment for M5-1 was assumed to be 100% impervious which is considered a conservative assumption (i.e., results in the maximum amount of flow). Surface depression storage in both catchments was assumed as 2 mm for impervious surfaces (reflecting paved parking surfaces) and 5 mm for pervious surfaces (reflecting landscaped areas).

G.2.3 Rainfall Data

Site rainfall was measured at an on-site rain gauge installed for the stormwater sampling program. Rainfall data at the site was provided on a 5-min time step for the following time periods:

- Event 1: August 19, 2015 0:00 to August 23, 2015 0:00;
- Event 2: October 28, 2015 0:00 to November 1, 2015 0:00;
- Event 3: November 18, 2015 12:00 to November 21, 2015 12:00; and
- Event 4: June 10, 2016 7:00 to June 14, 2016 23:55.

G.2.4 Verification Data

A flow monitoring station installed at the M2-1 discharge point was used to record the three runoff events in 2015 and one in 2016 (listed above). The total flow at the station for each of the four events is shown in Table G.1 below. Site rainfall records were compared to the flow records to estimate the amount of rainfall which contributed to the observed runoff; generally, this was assumed to be any rainfall within 3 hours prior to the start of runoff and the last recorded runoff at the monitoring station. The resulting rainfall volumes contributing to runoff are also shown in Table G.1 below.

Table G.1: M2-1 Measured Discharge Volumes

Event Number:	Rainfall Depth (mm)	Measured Flow at M2-1 (m^3)
Event 1 (Aug 2015)	5.0 (7mm over 24h)*	19.9
Event 2 (Oct 2015)	54.4	795
Event 3 (Nov 2015)	5.0 (5.8mm over 24h)*	7.76
Event 4 (June 2016)	25.4	201

* – the smaller rainfall depths were those that were considered to contribute to flow (i.e., rainfall before or after those events contributed to no or marginal flow).

The EPA SWMM5 model uses Soil Conservation Service (SCS) Curve Number method to estimate infiltration. This method uses an assumed curve number for soil (based on literature values) and associated empirically derived runoff responses to convert rainfall over the previous portion of a subcatchment area into runoff (in the impervious portion of the subcatchment, all rainfall becomes runoff). The method is further described in USDA "Urban Hydrology for Small Watersheds" (TR-55, 1986).

Verification of the model at M2-1 was completed by varying the curve number for the pervious area in the model (and thus the pervious area infiltration) until the model runoff approximately matched the measured runoff for the four measured storm events. A curve number was not required for M5-1 since this catchment is conservatively assumed to be 100% impervious, therefore a similar adjustment for M5-1 was not required.

G.2.5 Results and Discussion

The M2-1 catchment model was run for a range of curve numbers in order to estimate a best-fit to the measured data (based on difference in runoff volumes); ultimately a curve number of 89 was found to produce the best approximation. Based on the Design Chart 1.09 of the MTO Drainage Management Manual (2003), this value is equivalent to a farmstead over clay soils. The flow results using a curve number of 89 for the pervious area infiltration in the model are shown in Table G.2 below.

Table G.2: M2-1 Measured and Modeled Runoff

Event	Measured Flow at M2-1 (m^3)	Modeled Flow at M2-1 (m^3)	Difference (m^3)	Difference (%)
Event 1 (Aug 2015)	19.9	25.5	+5.6	+28%
Event 2 (Oct 2015)	795	739	-56.2	-7%
Event 3 (Nov 2015)	7.76	18.7	+10.9	+141%
Event 4 (Jun 2016)	201	196	-4.4	-2%

Generally, Event 2 and 4 possess the closest results presenting a modeled flow versus measured flow difference of less than 10%, while the modeled results of Events 1 and 3 are 28% and 141% greater than the logger recorded results for August and November, respectively. This is assumed to be the result of the small size of the storm events (both August and November storms were approximately 5 mm while the August and June events were 54.4 and 25.4 mm respectively), the result of which is that small changes in total event flow may have an exaggerated impact on the percent change. In addition, the Event 3 consisted of an intermittent storm with low rainfall resulting in some flow in two discrete periods within the 24hours and likely resulting in less predictable modelling.

The model results for M5-1 for the four storm events and a comparison of runoff volume versus depth of rainfall are shown in Table G.3 below. These values tend to be very sensitive to rainfall intensity since shorter, more intense rainfall generates more runoff than a less intense rainfall of equal volume, as well as surface storage since ponded water in a SWMM5 subcatchment must first exceed the surface storage depth before runoff occurs, which typically prevents runoff of the first 2-5 mm of rainfall.

Table G.3: M5-1 Model Results

Event	M5-1	
	Modeled Runoff Vol. (cu. m)	**Vol./Depth of Rainfall (m^3/mm)**
Event 1 (Aug 2015)	338	67.5
Event 2 (Oct 2015)	3,700	68.0
Event 3 (Nov 2015)	246	49.2
Event 4 (Jun 2016)	1,640	64.7

Three of the events have similar volume/depth of rainfall ratios and the one variation (Event 3) was considered a small and non-representative storm.

Figure G.1: Stormwater Sampling Locations