Canadian Nuclear Safety Commission | Commission canadienne de sûreté nucléaire

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Date signed/Signé le: 08 APRIL 2024

A Licensing Basis Amendment

Une modification au fondement d'autorisation

Ontario Power Generation Inc.

Pickering Waste Management Facility

Ontario Power Generation Inc.

Installation de gestion des déchets de Pickering

Hearing in writing based solely on written submissions

Audience par écrit fondée uniquement sur des mémoires

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Submitted by:

CNSC Staff

Soumis par :

Le personnel de la CCSN

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Summary

This CMD presents information about the following matter of regulatory interest with respect to Ontario Power Generation Incorporated (OPG):

- An application to amend the Pickering Waste Management Facility (PWMF) licensing basis to process and store a maximum of 100 dry storage containers containing a minimum of 6-year cooled fuel at the PWMF.

CNSC staff recommend the Commission consider taking the following actions:

- Amend the PWMF licensing basis to authorize OPG to process and store a maximum of 100 dry storage containers containing a minimum of 6-year cooled fuel at the PWMF.

The following items are attached:

- The current Waste Facility Operating Licence WFOL-W4-350.00/2028
- The proposed changes to the licence conditions handbook

Résumé

Le présent CMD fournit de l’information sur les questions d’ordre réglementaire suivantes concernant Ontario Power Generation Incorporated (OPG):

- Une modification au fondement d’autorisation de l’installation de gestion des déchets de Pickering (IGDP) en vue de traiter et d’entreposer un maximum de 100 conteneurs de stockage à sec de combustible refroidi pendant au moins 6 ans à l’IGDP.

La Commission pourrait considérer prendre les mesures suivantes:

- Modifier le fondement d’autorisation de l’IGDP pour autoriser OPG à traiter et à entreposer un maximum de 100 conteneurs de stockage à sec de combustible refroidi pendant au moins 6 ans à l’IGDP.

Les pièces suivantes sont jointes :

- Le permis d’exploitation d’une installation de déchets en vigueur, WFOL-W4-350.00/2028
- Les modifications proposées au manuel des conditions de permis (MCP)

Signed/Signé le

08 April 2024 / 08 avril 2024

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Executive Summary

The Pickering Waste Management Facility (PWMF) is located on the site of the Pickering Nuclear Generating Station (PNGS) on the North shore of Lake Ontario, in the city of Pickering, Ontario and lies within the traditional territory of the Michi Saagiig Anishinaabe people. These lands are covered by the Williams Treaty between Canada and the Mississauga and Chippewa Nations.

Ontario Power Generation Incorporated (OPG) owns and operates the PWMF under a Class IB Waste Facility Operating Licence (WFOL). At the PWMF, OPG processes and stores dry storage containers (DSCs) containing fuel cooled for a minimum of 10 years, generated from the operations at the PNGS.

In June 2023, OPG submitted an application requesting that the Commission amend the PWMF licensing basis to authorize OPG to process and store a maximum of 100 DSCs containing a minimum of 6-year cooled fuel at the PWMF. The DSCs would not be additional to the approved DSC inventory but would be included in the current approved total of 1,758 DSCs for the PWMF. OPG's request is to support future operational needs, where additional space in the PNGS Irradiated Fuel Bay B will be required for the unloading of 2 full unit cores.

OPG completed a safety assessment to assess the impact of processing and storing DSCs containing a minimum of 6-year cooled fuel at the PWMF. The safety assessment included:

1. a safety analysis to demonstrate that processing and storing 6-year cooled fuel would have negligible effects on the safe operations at the PWMF.
2. environmental protection considerations to determine that the change request would have negligible impact on the environment and the public.
3. design considerations to ensure compliance with regulatory requirements.

The purpose of this Commission Member Document (CMD) is to outline the CNSC's staff review of OPG's safety case, including conclusions and recommendations, to inform the Commission's decision on OPG's request to amend the PWMF licensing basis.

The public, Indigenous nations and communities, and stakeholders were invited to participate in this regulatory process. The CNSC Participant Funding Program provided up to approximately $42,000 to enable participation.

CNSC staff conclude that OPG's application:

- has demonstrated that processing and storing 6-year cooled fuel would have negligible effects on safe operations at the PWMF, and a negligible impact on the public and environment.
- has met the applicable regulatory requirements.

Therefore, CNSC staff recommend that the Commission amend OPG's PWMF licensing basis to authorize OPG to process and store a maximum of 100 DSCs containing a minimum of 6-year cooled fuel at PWMF.

Referenced documents in this CMD are available to the public upon request, subject to confidentiality considerations.

CMD Structure

This Commission Member Document (CMD) is presented in 2 parts.

Part 1 of this CMD includes:

1. an overview of the matter being presented;
2. overall conclusions and recommendations;
3. discussion about the recently published Pickering environmental protection review report;
4. general discussion pertaining to the safety and control areas (SCAs) that are relevant to this CMD;
5. discussion about engagement with Indigenous Nations and communities; and
6. appendices that complements items 1 through 5.

Part 2 of this CMD provides all available information pertaining directly to the current and proposed licensing basis amendment.

1. Overview

1.1 Background

Ontario Power Generation (OPG) owns and operates the Pickering Waste Management Facility (PWMF) under a Class IB Waste Facility Operating Licence (WFOL) WFOL-W4-350.00/2028, valid from April 1, 2018, to August 31, 2028 [1].

At the PWMF, OPG receives, processes, and stores dry storage containers (DSCs) containing used nuclear fuel (high-level radioactive waste) generated at the Pickering Nuclear Generating Station (PNGS). OPG also manages intermediate-level radioactive waste at the Retube Component Storage Area (RCSA).

1.2 PWMF Location and Layout

The PWMF is in the Province of Ontario on the North shore of Lake Ontario, in the city of Pickering and the regional municipality of Durham and lies within the traditional territory of the Michi Saagiig Anishinaabe people. These lands are covered by the Williams Treaty between Canada and the Mississauga and Chippewa Nations. The facility lies 32 km northeast of downtown Toronto and 21 km southwest of Oshawa.

The PWMF spans over two areas, Phase I and Phase II as pictured in Figure 1. Phase I is located within the protected area of the PNGS and consists of one DSC processing building, two DSC storage buildings (SB) #1 and SB#2 and the RCSA. Phase II of the PWMF is located north-east of Phase I and is contained within its own protected area, separate from the protected area of the PNGS, but within the Pickering site. Phase II contains SB#3 and SB#4. The PWMF WFOL currently authorizes OPG to construct two additional SB#5 and SB#6.

Figure 1 - Aerial view of the PWMF

1.3 PWMF Operations

At the PWMF, OPG receives DSCs containing cooled nuclear fuel generated at the PNGS. The DSCs are then processed which includes vacuum drying, welding, and painting of the DSC. The processed DSCs are then transferred and stored in SB#1, SB#2, SB#3, and SB#4.

OPG also manages the intermediate-level radioactive waste in dry storage modules (DSM) at the RCSA, generated from the refurbishment of the PNGS Units 1- 4. The RCSA is closed to the receipt of any new intermediate-level radioactive waste. The DSMs in the RCSA undergo periodic inspections, as well as regular monitoring and maintenance; however, no additional storage of waste has been inputted in the RCSA since 1993.

1.4 Highlights

In February 2018, the Commission renewed OPG's WFOL for the PWMF [2] for a period of 10 years. At the time, OPG's application including the safety assessment was based on processing and storing DSCs containing a minimum of 10-year cooled fuel at the PWMF.

In November 2020, OPG submitted a proposal to CNSC staff to store 6-year cooled fuel at the PWMF. CNSC staff's review determined that OPG's proposal would result in a change to the Commission approved licensing basis [2] submitted by OPG in support of the last license renewal.

In June 2023, OPG submitted a licensing basis amendment application [3] requesting Commission authorization, to process and store a maximum of 100 DSCs containing a minimum of 6-year cooled fuel at the PWMF. The DSCs would not be additional to the current approved DSC inventory of 1,758 DSCs. The PWMF licensing basis allows OPG to process and store DSCs containing a minimum of 10-year cooled fuel.

OPG's request is to support future operational needs, where additional space in PNGS IFB-B is required for the unloading of two full unit cores.

The licensee completed a safety assessment to assess the impact of processing and storing DSCs containing a minimum of 6-year cooled fuel at the PWMF. The safety assessment provided predicted values of elevated temperatures and dose rates anticipated for DSCs containing minimum 6-year cooled fuel, and also included 1) a safety analysis to demonstrate that processing and storing 6-year cooled fuel has negligible effects on the safe operations at the PWMF, 2) environmental assessment to determine that the change request will have negligible impact on the environment and the public, and 3) design considerations to ensure compliance with the regulatory requirements.

The operational activities and their associated procedures that comprise processing and storing DSCs will remain the same. Furthermore, OPG's assessment indicates that there will be no changes made to the design of the DSC, the processing building, or the SBs.

The purpose of this Commission Member Document (CMD) is to provide CNSC staff's conclusions and recommendations to support the Commission's decision on OPG's licensing basis amendment application, requesting processing and storage of a maximum of 100 DSCs containing a minimum of 6-year cooled fuel at the PWMF.

This CMD includes information on CNSC staff's review of OPG's application and supporting documents, with information on:

1. The environmental protection review performed by CNSC staff.
2. CNSC staff performance assessments in safety and control areas (SCAs) of relevance to the proposal during the current licence period, including OPG's safety case.
3. Engagement with the public and Indigenous Nations and communities.

1.5 Overall Conclusions

CNSC staff's assessment of OPG's application including the supporting documents concludes the following:

1. OPG has demonstrated that the design considerations for processing and storing up to 100 DSCs with 6-year cooled fuel meet the regulatory requirements.
2. OPG has adequately assessed the hazards associated with licensed and proposed activities through safety assessments and demonstrated an adequate level of protection of the workers, the public, and the environment over a broad range of operating conditions.
3. OPG remains qualified to carry on the activities authorized in the WFOL and continues to make provisions to protect workers, people, and the environment, and support Canada's international commitments to non-proliferation.

1.6 Overall Recommendations

CNSC staff recommend that the Commission:

1. Amend the PWMF licensing basis to authorize OPG to process and store a maximum of 100 DSCs containing a minimum of 6-year cooled fuel at PWMF.

If the Commission accepts CNSC staff's recommendation,

a. CNSC staff will revise the PWMF LCH as specified in Part 2 of this submission.

2. Matters for Consideration

2.1 Environmental Protection Review

CNSC staff reviewed OPG's application to identify which type of environmental review was required to be conducted, if applicable. As part of this process, CNSC staff assessed whether a federal lands review under the *Impact Assessment Act* (IAA) is required. For this licensing basis amendment application, federal lands review was not required because the application does not include activities that meet the definition of a project on federal lands.

CNSC staff conduct environmental protection reviews (EPRs) for all license applications with potential environmental interactions, in accordance with the CNSC's mandate under the NSCA and associated Regulations. The EPR may inform the Commission's conclusion on whether the proposal provides adequate protection of the environment and the health of people.

CNSC staff's assessment included a review of the application and supporting documents, including the environmental risk assessment, the predictive effects assessment, annual compliance monitoring reports, and past environmental performance for the facility. As mentioned in section 3.6, CNSC staff have found that the information provided by OPG regarding environmental protection is sufficient to meet the applicable regulatory requirements under the NSCA and associated Regulations.

Additionally, CNSC staff prepared an EPR report for the Pickering Nuclear Site that summarizes the environmental performance of the PNGS and the PWMF from 2016-2022. The report is available on the CNSC website.

CNSC staff will continue to verify and ensure that, through ongoing licensing and compliance activities and reviews, the environment and the health of persons are protected and will continue to be protected.

2.2 Relevant Safety and Control Areas

The functional areas of any licensed facility or activity consist of a standard set of SCAs. CNSC staff examined each SCA and their relevance to this CMD based on the impact of OPG's request on the licensing basis documentation for a given SCA. CNSC staff assessed OPG's application for all SCAs.

OPG's proposed change to the licensing basis for authorization to store 6-year cooled fuel did not trigger changes to certain OPG governance and program documents, meaning there were no changes within those SCAs, therefore these SCAs have been excluded in this CMD.

Functional Area	Safety and Control Area	Relevant to this CMD?
Management	Management System	No
	Human Performance Management	No
	Operating Performance	Yes
Facility and Equipment	Safety Analysis	Yes
	Physical Design	Yes
	Fitness for Service	Yes
Core Control Processes	Radiation Protection	Yes
	Conventional Health and Safety	No
	Environmental Protection	Yes

Functional Area	Safety and Control Area	Relevant to this CMD?
	Emergency Management and Fire Response	No
	Waste Management	No
	Security	No
	Safeguards and Non-Proliferation	Yes
	Packaging and Transport	No

2.3 Other Matters of Regulatory Interest

The following table identifies other matters that are relevant to this CMD.

Other Matters of Regulatory Interest	
Area	**Relevant to this CMD?**
Indigenous Consultation and Engagement	Yes
Other Consultation	No
Cost Recovery	No
Financial Guarantees	No
Improvement Plans and Significant Future Activities	No
Licensee's Public Information Program	Yes
Nuclear Liability Insurance	No

3. General Assessment of SCAs

This section provides information, organized by SCA, regarding CNSC staff's assessment of OPG's PWMF licensing basis amendment application [3] and addendum [4] requesting Commission authorization to process and store a maximum of 100 DSCs containing a minimum of 6-year cooled fuel at the PWMF. CNSC staff's assessment considered information gathered during the current licence period, from 2018 through to the end of 2023.

In this section, CNSC staff have included SCAs that are most relevant in providing a good overall indication of how regulatory requirements will be met, and if OPG's request impacts the licensing basis documentation for a given SCA.

The specific areas (SpAs) that comprise the SCAs for this facility or activity type are identified in Appendix B, section B.2. If SpAs are not listed for a given SCA in section 3, then a decision has been made to encompass them in an overall approach to that SCA.

3.1 Operating Performance

The operating performance SCA includes an overall review of the conduct of licensed activities and the activities that enable effective operating performance.

The SpAs that comprise this SCA at the facility include:

- Conduct of licensed activity
- Procedures
- Reporting and trending

3.1.1 Discussion

OPG is required by its licence to implement and maintain an operating program, which includes a set of operating limits, and to maintain a program for reporting to the Commission or an authorized person. The operating limits and conditions for the PWMF are contained in the safety report [5]. CNSC staff verify that OPG has policies, programs, methods, and procedures in place for the safe operation and maintenance of its licensed nuclear facility. REGDOC-3.1.2*, Reporting Requirements, Volume I: Non-Power Reactor Class I Facilities and Uranium Mines and Mills*, is also applicable in providing requirements for reporting on operating performance.

Verification of the licensee's compliance with the requirements of this SCA are included as part of CNSC's compliance activities ranging from desktop reviews of quarterly and annual reports, reviews of event reports, related corrective actions, and inspections.

OPG provides a summary of compliance against these operating limits and conditions as part of their quarterly and annual reports to the CNSC. CNSC staff reviewed this information and confirmed that the facility has operated within the operating limits and conditions for the facility.

3.1.2 Impact of OPG's Proposal on the Operating Performance SCA

Conduct of Licensed Activity

The process of processing and storing DSCs containing a minimum of 6-year cooled fuel will remain the same as processing and storing DSCs containing a minimum of 10-year cooled fuel. The DSCs containing 6-year cooled fuel will be processed at the DSC processing building, moved to SB#1 for the application of safeguards seals in the International Atomic Energy Agency (IAEA) surveillance area and then transferred for storage in SB#3 at the PWMF. When the DSCs reach the minimum cooling period of 10 years, the DSCs will be managed the same as the other DSCs in the SBs.

OPG's assessment indicates that there will be no changes made to the design of the DSC, the processing building as well as the SB. OPG's proposal will have the effect of increased thermal gradient and higher irradiation on the DSCs due to loading younger fuel. The licensee will initially load two to four DSCs, with each DSC containing four full modules (384 bundles) of 6-year cooled fuel, to confirm that the DSC temperature and dose measurements meet the modelling predictions, supported by the operational experience from the loading and storage of one DSC (0024) containing four modules of 6-year cooled fuel which was successfully completed at the PWMF in 1998.

Should the Commission authorize the licensee's request, OPG will be providing the following information to CNSC staff after the initial loading of two to four DSCs with 6-year cooled fuel at PWMF:

- Confirmatory dose rate survey results
- DSC outer surface and weld surface temperatures

OPG has committed [6] to only proceed from the commissioning test trial of the two to four DSCs to the processing of additional DSCs after CNSC staff review the field measurements and conclude that the results are acceptable via written acceptance. This will include IAEA review to confirm the safeguards measures.

Procedures

OPG has a process in place to ensure that procedures are developed and changes to them are managed consistently to support the safe operations and maintenance of the facility.

CNSC staff review procedural-level documents as part of ongoing compliance verification activities to ensure proper maintenance of procedures to reflect actual practices as well as procedural adherence by OPG personnel. The current [7] (and proposed) Licence Conditions Handbook (LCH) identifies licensing basis program documentation and stipulates requirements for providing change notification, which triggers reviews by CNSC staff to ensure changes continue to align with regulatory requirements and the facility licensing basis.

OPG's change request will result in minor changes to the licensing basis and the operational documentation and procedures. The PWMF Safety Report is a licensing basis program document that requires notification of change. The licensee has committed to provide to CNSC staff an appendix to the safety report, if the commissioning trial of two to four initial DSCs containing 6-year cooled fuel has concluded successfully.

OPG's document, *Operating Policies and Principles, Pickering Waste Management Facility*, is a licensing basis program document that requires notification of change. Should the Commission amend the licensing basis, OPG has committed to updating the document.

Reporting and Trending

OPG's documents N-PROG-RA-0002, *Conduct of Regulatory Affairs* and N-PROC-RA-0020, *Preliminary Event Notification* ensure that events are reported in accordance with regulatory requirements. OPG's request does not impact the reporting regulatory requirements.

3.1.3 Summary

A summary of the licensee's past performance, challenges and proposed improvements are presented in the following subsections.

3.1.3.1 Past Performance

CNSC staff have assessed the Operating Performance SCA for this facility. During the current licensing period, OPG met the regulatory requirements for the Operating Performance SCA.

3.1.3.2 Regulatory Focus

CNSC staff will continue to monitor OPG's performance in this SCA through regulatory oversight activities including inspections and desktop reviews of relevant program documentation. CNSC staff will focus on procedural adherence and maintenance of the operating limits and safety envelope with compliance verification focus on the safe conduct of licensed activities.

3.1.3.3 Proposed Improvements

CNSC staff did not identify any improvements related to the Operating Performance SCA.

3.1.4 Conclusion

CNSC staff conclude that OPG continues to meet the regulatory requirements related to the Operating Performance SCA. Based on CNSC staff assessment of OPG's application including supporting documents and past performance, OPG's operating program is adequate for the proposed licensing basis amendment.

3.2 Safety Analysis

The Safety Analysis SCA covers the maintenance of the safety analysis that supports the overall safety case for the facility. Safety analysis is a systematic evaluation of the potential hazards associated with the conduct of a proposed activity or facility and considers the effectiveness of preventative measures and strategies in reducing the effects of such hazards.

The SpAs that comprise this SCA at the facility include:

- Deterministic safety analysis
- Hazard analysis

3.2.1 Discussion

Paragraph 3(1)(i) of the *General Nuclear Safety and Control Regulations* requires that a description and the results of any test, analysis or calculation performed to substantiate the information be included in the application. Paragraph 6(c) of the *Class I Nuclear Facilities Regulation* requires that an application for a licence to operate include a final safety analysis report.

The purpose of the safety analysis report is to confirm that the consequences of a range of events are acceptable. It includes an integrated assessment of the facility to demonstrate, among other things, adequate safety for external events such as fires, floods, and tornados, and adequate protective features to ensure the effects of an event do not impair safety related systems, structures, and components.

OPG has implemented and maintains a safety analysis program at the PWMF in accordance with regulatory requirements. As per PWMF's LCH [7], OPG is required to provide an updated safety report at a minimum of once every five years.

The previous safety report was updated in 2018 (Revision 006) [5]. In November 2023, OPG submitted Revision 007 of the safety report which is currently under review by CNSC staff [8].

OPG's application [3][4] included an enclosure to the safety assessment for storing lower aged fuel in SB#3 at PWMF. The report provides an assessment of potential consequences and demonstrates the safety case through defence in depth.

3.2.2 Impact of OPG's Proposal on the Safety Analysis SCA

OPG's request to process and store DSCs containing 6-year cooled fuel at the PWMF is not within the Commission approved licensing basis [2]; the licensee's proposed activity will result in a change to the licensing basis, that was submitted to the Commission in support of the last licence renewal.

CNSC staff evaluated the information provided in OPG's application including the safety assessment and determined that the licensee has adequately assessed the hazards associated with licensed activities and demonstrated an adequate level of protection over a broad range of operating conditions.

As part of the application, OPG assessed impact on, and performed re-analyses of the identified aspects of, the deterministic safety analysis, as presented in the overall description in the previous subsection. Furthermore, OPG assessed impact on the hazards analysis and determined that there is no change in the results of the hazard analysis. Namely, the list and the category of the hazards, postulated initiating events and resulting accidents have not changed.

3.2.2.1 CNSC Staff Review of OPG's Safety Assessment

CNSC staff reviewed OPG's application including the safety assessment for the dry storage of minimum 6-year cooled fuel at PWMF.

With respect to normal operation, the results of the safety assessments are consistent with operating experience gained during the interim storage of one DSC containing 6-year cooled fuel, completed at the PWMF in 1998 as further discussed in the next section. There would be no significant changes of safety related parameters during normal operations.

As for the accident scenarios, the licensee performed and submitted updated assessment of postulated accidents. CNSC staff reviewed the results and confirmed that the changes were insignificant and that the results of the safety assessments confirm that acceptance criteria, which are used in the existing safety analysis report, are met for the dry storage of minimum 6-year cooled fuel at the PWMF.

CNSC staff review concluded that the safety assessment included in OPG's application provides sufficient information and meets the requirement of paragraph 6(c) of *Class I Nuclear Facilities Regulation*.

3.2.2.2 OPEX from DSC 0024

CNSC staff assessment of OPG's application determined that OPG has a positive operational experience, which is directly relevant to the proposed activity. Namely, one DSC (0024) was loaded with four modules of 6-year cooled fuel. Its performance was observed, measurements of temperatures and other parameters were conducted. The project was successfully completed at the PWMF in 1998.

It provided evidence that the DSC performance and the temperatures met applicable regulatory requirements. Furthermore, it provided a validation basis for the assessment of temperatures and other parameters in OPG's application.

Based on the operational experience of the DSC (0024), it was determined that temperature measurements were approximately 40 °C lower than those in the safety assessment of the current application. This OPEX, along with the modelling predictions, provides a technical basis for the expectation that contact temperatures and, correspondingly, fuel cladding temperature will be within the safety limits during the proposed project involving the load of two to four DSCs.

3.2.3 Summary

A summary of the licensee's past performance, challenges and proposed improvements is presented in the following subsections.

3.2.3.1 Past Performance

OPG has performed several safety assessments to ensure the safety of its operations as part of the continued improvement of safety analysis.

Hazard analysis and selection of credible accident conditions has been performed using probabilistic approaches. Demonstration of safety in credible scenarios was performed using deterministic approaches. Both probabilistic and deterministic approaches were established and maintained by OPG in a consistent manner during the current licensing period.

3.2.3.2 Regulatory Focus

CNSC staff continue to monitor OPG's performance in this area through regulatory oversight activities including desktop reviews and inspections of OPG's compliance reporting and revisions to relevant program documentation pertaining to this SCA.

3.2.3.3 Proposed Improvements

CNSC staff did not identify any improvements related to the Safety Analysis SCA with respect to the PWMF.

3.2.4 Conclusion

The proposed change to the licensed activity is not expected to have adverse impacts on the safety analysis SCA. To confirm this expectation, the licensee has committed to provide the confirmatory dose rate surveys and DSC outer surface and weld surface temperatures to CNSC staff for review.

3.3 Physical Design

The SCA Physical Design relates to activities that impact the ability of structures, systems and components to meet and maintain their design basis given new information arising over time and taking changes in the external environment into account.

The SpAs that comprise this SCA at the facility include:

- Design governance
- Structure design

- System design
- Component design

3.3.1 Discussion

The licensee has maintained an effective design program, implementing design modifications to the facility using established Engineering Change Control (ECC) process to maintain the design basis and licensing basis. Implementation of design modifications to the facility has been the subject of ongoing compliance monitoring activities performed by CNSC staff, which includes reviews of quarterly and annual compliance reports.

OPG has consistently complied with the design program and implemented design modifications in accordance with the established ECC process. There have been no adverse findings on design modifications in relation to the DSCs or SBs.

The DSCs are conservatively designed to provide a storage life of 50 years for used fuel and to meet all shielding and containment integrity requirements over this period. Based on their current condition, the DSCs are expected to be able to perform adequate shielding and containment functions beyond 50 years.

3.3.2 Impact of OPG's proposal on Physical Design SCA

OPG's proposal will have the effect of increased thermal gradient and higher irradiation on the DSCs due to loading younger fuel. From a Physical Design perspective, this will lead to increased thermal loads on the DSCs and increased contact temperature of the DSCs on the interfacing systems during the DSC processing and storage process. Examples of interfacing systems include transfer clamp, workshop heating and ventilation system, transporter camera, phased array ultrasonic testing (PAUT) system for weld inspection, and IAEA surveillance cameras in the processing building.

Based on OPG's modelling predictions as well as OPEX from DSC 0024, OPG's proposal is not expected to have adverse impact on the physical design of the DSCs as well as the SB. The licensee presented temperature measurements of DSC 0024 loaded with 6-year cooled fuel from 1998 (60.9°C inner liner and 42.3°C outer liner) and conservatively identified contact temperature of 85°C from conservative design analyses in 2022. OPG presented analyses predicting that the thermal stresses produced from 6-year cooled fuel stored in a DCS will not compromise the containment and shielding functions of the DSC under processing and storage conditions. Additional constraints are identified so that the interfacing systems with DSCs will not be adversely impacted during the dry storage process. For example, DSCs with minimum 6-year cooled fuel shall have weld surface temperature below 50 ºC at the time of PAUT inspection.

OPG continues to implement a comprehensive pressure boundary program at PWMF. OPG has a formal service agreement with the Technical Standards and Safety Authority (TSSA) as the Authorized Inspection Agency (AIA) and maintains the formal agreement with the TSSA. As a result of the verification activities, CNSC staff agree that there are not any impacts on pressure boundary program for OPG's proposal to process and store 6-year-old used fuel at the PWMF.

OPG's proposal of storage of minimum 6-year cooled fuel will not require change of design basis and licensing basis documents listed in the LCH.

3.3.3 Summary

A summary of the licensee's past performance, challenges and proposed improvements are presented in the following subsections.

3.3.3.1 Past Performance

OPG has satisfied the compliance verification criteria and regulatory expectations under the Physical Design over the current licensing period.

3.3.3.2 Regulatory Focus

To supplement the data relied upon, the licensee plans to initially load 2 or 4 DSCs with 6-year cooled fuel to confirm temperature and dose measurements before processing of additional DSCs with minimum 6-year cooled fuel. CNSC staff will follow up with the initial temperature measurements to re-affirm that they would not indicate unacceptable thermal loads on the DSCs and contact temperatures for interfacing systems.

3.3.3.3 Proposed Improvements

CNSC staff did not identify any improvements related to the Physical Design SCA with respect to the PWMF.

3.3.4 Conclusion

The proposed change to the licensed activity is not expected to have adverse impacts on the Physical Design SCA.

3.4 Fitness for Service

The SCA fitness for service covers activities that impact the physical condition of structures, systems, and components to ensure that they remain effective over time. This area includes an integrated set of programs that ensure all equipment is available to perform its intended design function when called upon to do so. The specific areas that comprise this SCA at the facility relevant to this CMD include:

- Aging Management

3.4.1 General Discussion

The licensee has mature programs to assess the effects of aging on the SBs and DSCs at the PWMF. Implementation of the aging management programs and findings are the subject of ongoing compliance monitoring activities completed by CNSC staff, which includes:

- review of revisions to aging management program governance documents;
- review of quarterly facility reports on PWMF operation;
- review of annual reports summarizing activities completed in accordance with licensee aging management programs; and
- completion of compliance monitoring inspections.

OPG has consistently complied with the aging management programs, completing inspections in accordance with established schedules and reporting results to CNSC staff. There have been no adverse findings of aging related degradation of SBs or DSCs. The DSCs are expected to be able to perform containment functions for used fuel well beyond the originally proposed operational life of 50 years based on their current condition.

3.4.2 Impact of OPG's Proposal on the Fitness for Service SCA

Storage of 6-year cooled fuel as opposed to 10-year cooled fuel could result in higher thermal loads and irradiation dose on the DSCs. There will be no short-term impact on the condition of the DSCs and preliminary evaluations by OPG have indicated that these changes will have negligible impact on aging of the DSCs. The expected temperature and irradiation increases associated with the storage of younger fuel are not sufficient to impact the integrity of the DSC materials in the short or long term. This was demonstrated through analytical calculations and with the instrumentation of a DSC containing 6-year cooled fuel in 1998. Based upon available information, CNSC staff are satisfied with the licensee's conclusions based upon available information.

The licensee has implemented the necessary provisions to continue to demonstrate DSC fitness for service to support safe storage of the used fuel.

3.4.3 Summary

A summary of the licensee's past performance, challenges and proposed improvements are presented in the following subsections.

3.4.3.1 Past Performance

OPG has satisfied the compliance verification criteria and regulatory expectations under the Fitness for Service SCA over the course of the current licensing period.

3.4.3.2 Regulatory Focus

Theoretically, higher thermal loads and irradiation doses associated with 6-year cooled fuel could increase aging of DSCs although, in practice, this is not expected to be the case based on the preliminary evaluations assessed by OPG using analytical calculations and data from an instrumented DSC in 1998. To date, there has been no significant aging related degradation of DSCs, but aging management program activities continue to be based on conservative assumptions regarding the potential for degradation.

CNSC staff will monitor the licensee's activities to assess the condition of the DSCs loaded with 6-year cooled fuel to verify that there are no adverse impacts on DSC aging.

3.4.3.3 Proposed Improvements

CNSC staff did not identify any improvements related to the Fitness for Service SCA with respect to the PWMF.

3.4.4 Conclusion

The proposed change to the licensed activity is not expected to have adverse impacts on the fitness for service of the SBs or dry storage containers. To confirm this expectation, the licensee has committed to additional condition monitoring of the first DSCs containing 6-year cooled fuel and adjusting aging management activities, if necessary. Hence, the proposed licensing basis change is considered to have a neutral impact on safety.

3.5 Radiation Protection

The radiation protection SCA covers the implementation of a radiation protection program in accordance with the *Radiation Protection Regulations*. The program must ensure that contamination levels and radiation doses received by individuals are monitored, controlled, and maintained as low as reasonably achievable (ALARA).

The SpAs that comprise this SCA at the PWMF include:

- Application of ALARA
- Worker dose control
- Radiation protection program performance
- Radiological hazard control

3.5.1 General Discussion

The *Radiation Protection Regulations* require licensees to establish a radiation protection program to keep exposures ALARA, taking economic and social factors into account, through the implementation of a number of control programs, including:

- Management control over work practices
- Personnel qualification and training
- Control of occupational and public exposures to radiation
- Planning for unusual situations

OPG’s radiation protection program and its associated supporting governance documents are designed to address the requirements in the *Radiation Protection Regulations*. CNSC staff’s assessment of OPG’s programs within this SCA has determined that OPG has implemented and maintained an effective radiation protection program at the PWMF that meets regulatory requirements.

Details pertaining to the specific areas within this SCA are presented in the following subsections.

Application of ALARA

OPG’s commitment to the as low as reasonably achievable (ALARA) principle has been demonstrated through the implementation of the radiation protection program at the PWMF. OPG’s radiation protection program adheres to the ALARA principle by integrating ALARA measures into planning, scheduling, and work control; and by monitoring performance against ALARA targets for work conducted at the PWMF.

CNSC staff are satisfied with OPG's efforts in applying the ALARA principle to keep worker doses ALARA over the licence period.

Worker Dose Control

OPG's radiation protection program is designed to ensure that doses to workers are controlled and do not exceed regulatory limits. During the licence period, OPG has maintained radiation doses to workers below regulatory dose limits as shown in Table 1 below.

Table 1: Average and maximum individual effective doses of NEWs at the PWMF from 2018-2022

	2018	2019	2020	2021	2022	Regulatory Limit
Average Effective Dose	0.60 mSv	0.40 mSv	0.60 mSv	0.50 mSv	0.61 mSv	-
Maximum Individual Effective Dose	1.50 mSv	0.90 mSv	1.30 mSv	1.40 mSv	1.18 mSv	50 mSv/year

OPG uses a combination of action levels, staff training and qualification, dose management tools (work planning and management oversight), and personal protective equipment to ensure radiation doses to workers are controlled and kept ALARA. Action levels are established for unplanned dose, and for contamination control. During the current licence period, there have been no action level exceedances related to dose to workers.

CNSC staff are satisfied with OPG's efforts over the current licence period in controlling the radiation doses to workers at PWMF.

Radiation Protection Program Performance

The oversight applied by OPG in implementing and improving its radiation protection program is effective in protecting workers at PWMF.

CNSC staff are satisfied with the performance of OPG's radiation protection program at PWMF over the licence period.

Radiological Hazard Control

OPG's radiation protection program requires monitoring and control of all radiological hazards at the PWMF. The program measures related to radiological hazard control include radiological zoning, contamination control, dose rate control, and area and airborne radiation monitoring and control. During the current licence period, there have been no contamination control events in which the levels exceeded OPG's contamination control action level for the PWMF.

CNSC staff are satisfied with OPG's efforts to continue to implement its radiological hazard controls to protect workers and ensure radioactive contamination is controlled within the PWMF site boundaries.

3.5.2 Impact of OPG's Proposal on the Radiation Protection SCA

Presently, OPG is only licensed to process minimum 10-year cooled fuel at PWMF. The proposed reduction in cooling time will result in a higher radionuclide inventory in the 6-year cooled fuel relative to the 10-year cooled fuel. Consequently, this will result in higher dose rates around the DSCs holding 6-year cooled fuel [3][4].

CNSC staff reviewed OPG's proposal from a radiation protection perspective against OPG's program document N-PROG-RA-0013, *Radiation Protection*, and no gaps were identified. OPG stated that it will continue to implement its radiation protection program, which includes work planning, use of radiation exposure permits, dose monitoring, and dose rate monitoring to ensure that doses remain ALARA [3][4].

Application of ALARA

Based on the information provided in OPG's application, doses to workers will remain well below both the regulatory effective dose limit (50 mSv in a one-year dosimetry period) and OPG's Administrative Control Limit (20 mSv per year).

Should this project be authorized by the Commission, OPG will continue to implement its radiation protection program, which includes action levels and administrative limits, to ensure doses to workers are kept ALARA.

CNSC staff are satisfied with OPG's efforts in applying the ALARA principle to keep worker doses ALARA and assess that OPG's radiation protection program elements related to the application of ALARA are suitable for the proposed license amendment.

Worker Dose Control

Using conservative assumptions associated with the handling and loading of DSCs containing 6-year cooled fuel, OPG calculated a maximum individual effective dose to a PWMF worker of 2.73 mSv [9]. If the project is approved, OPG will apply the provisions of their radiation protection program and perform a dose assessment to validate the projected doses received by workers from DSC operations immediately after the loading of the trial DSCs [6].

OPG calculated the maximum dose during a postulated accident scenario involving a DSC with 6-year cooled fuel to be 5.92 mSv to a NEW [3][4]. The same accident condition involving a DSC with 10-year cooled fuel was calculated in the current safety report, resulting in a bounding dose of 5.0 mSv to a NEW [5]. Based on this analysis, doses to NEWs will be maintained below dose limits for postulated accidents.

CNSC staff are satisfied with OPG's efforts in controlling the radiation doses to workers at PWMF and assess that OPG's radiation protection program elements related to worker dose control are suitable for the proposed license amendment.

Radiological Hazard Control

CNSC staff are satisfied with OPG's efforts to continue to implement their radiological hazard controls to protect workers and ensure radioactive contamination is controlled at PWMF. CNSC staff assess that OPG's radiation protection program elements related to radiological hazard control are suitable for the proposed license amendment.

3.5.2.1 CNSC Staff Review of Dose Rate Assessment Considering Lower Aged Fuel in SB#3

OPG has estimated that dose rates from a DSC containing 6-year cooled fuel are expected to be approximately 2.6 times higher than the dose rates from a DSC containing 10-year cooled fuel [3][4].

Although the DSCs containing 6-year cooled fuel are predicted to emit higher dose rates, the emplacement and storage of these DSCs will be strategic such that other DSCs with older fuel will provide shielding. This will ensure that dose rates in the facility and surrounding areas will be managed and maintained as low as reasonably achievable.

OPG has stated that the dose rate targets used at PWMF will continue to be met if this project is authorized by the Commission. OPG has committed to monitoring dose rates and taking mitigating actions, as required [4][6]. CNSC staff are satisfied with OPG’s calculations and commitments and will verify actual dose rate results to ensure they do not pose an unreasonable risk to workers if the proposed project is approved.

Based on the information provided by OPG, CNSC staff are satisfied that doses will remain within the regulatory limits.

3.5.3 Summary

A summary of the licensee’s past performance, challenges and proposed improvements are presented in the following subsections.

3.5.3.1 Past Performance

CNSC staff have assessed OPG’s programs under the radiation protection SCA at the PWMF and found that OPG continues to meet regulatory requirements. OPG has maintained satisfactory performance across the specific areas of this SCA during the licence period.

3.5.3.2 Regulatory Focus

CNSC staff will continue to verify OPG’s performance and compliance in all aspects of the radiation protection SCA and verify that the protection of workers is optimized and that worker doses are kept ALARA.

If approved, CNSC staff will verify that OPG is performing the dose rate measurements and dose assessments as committed in their application.

3.5.3.3 Proposed Improvements

CNSC staff did not identify any improvements related to the radiation protection SCA with respect to the PWMF.

3.5.4 Conclusion

The proposed change is expected to result in increased dose rates and worker doses at the PWMF from the processing, handling, and storage of DSCs containing 6-year cooled fuel. OPG’s existing radiation protection program is expected to be able to manage the projected increase in doses to workers and maintain them ALARA.

3.6 Environmental Protection

The environmental protection SCA covers programs that identify, control, and monitor all releases of radioactive and hazardous substances and effects on the environment from facilities or as the result of licensed activities.

This CMD covers the following SpAs:

- Environmental management system (EMS)
- Effluent and emissions control (releases)
- Assessment and monitoring
- Protection of people
- Environmental risk assessment

3.6.1 General Discussion

OPG's environmental protection program includes policies, station instructions, methods, and procedures to identify, control, and monitor releases of radioactive and hazardous substances from the PWMF into the environment, and to protect the health and safety of people and the environment. CNSC staff confirm that OPG maintains an environmental protection program that meets regulatory requirements. CNSC staff have verified the performance of the environmental protection program through compliance activities including technical assessment of reports, event report reviews, and inspections.

The following sections detail CNSC staff's assessment of the SCA across the relevant specific areas. Additional information on CNSC staff's assessment of the environmental protection SCA can be found in the EPR report for the Pickering Nuclear Generating Site on CNSC's website.

3.6.2 Impact of OPG's proposal on Environmental Protection SCA

Environmental Management System (EMS)

OPG has established and implemented an EMS in accordance with CNSC REGDOC-2.9.1 - *Environmental Protection Policies, Programs and Procedures* and is registered to the CSA ISO 14001 *Standard, Environmental Management Systems – Requirements with Guidance for Use*.

OPG's environmental management and its supporting governing documents establish the provision of the protection of the environment at the Pickering Site and continual improvement of environmental performance as required by CNSC REGDOC-2.9.1. CNSC staff do not foresee OPG's licensing basis amendment request impacting OPG's EMS.

Effluent and Emissions Control

OPG continues to implement and maintain an effluent and emissions monitoring program at the facility as required by the *Class I Nuclear Facilities Regulation*. OPG's effluent and emissions monitoring program defines the methods and procedures for controlling and monitoring radioactive and hazardous substances, identifies and monitors discharge pathways for releases to the environment, and maintains releases below regulatory limits and action levels.

Releases are maintained low through administrative controls and a High Efficiency Particulate Air (HEPA) ventilation system. Radiological releases to air from the facility are well below the licence limit and the action level. There is no liquid effluent from the facility operations.

Based on compliance activities, CNSC staff confirm that the effluent and emissions monitoring program currently in place for the Pickering Site continue to protect human health and the environment and there are no foreseen revisions to the effluent and emissions monitoring program required as a result of the proposed amendment.

Assessment and Monitoring

OPG's environmental monitoring program is designed to measure environmental radioactivity and radiation in the vicinity of the Pickering site which includes the waste facility. Based on this program, environmental samples from different pathways of the food chain are collected from various offsite locations and analyzed. Data from the program are also used to assess public doses resulting from the routine operation of the Pickering Site, and to verify predictions made in environmental risk assessments. There are no anticipated changes to the monitoring program as a result of this proposed amendment.

OPG discontinued reporting stormwater monitoring results as of the first quarter of 2022. Prior to the first quarter of 2022, stormwater and foundation drainage associated with the facility were sampled weekly for tritium and gross gamma and provided to CNSC staff on a quarterly basis. Stormwater and foundation drainage are primarily influenced by air emissions from the adjacent NGS (tritium in precipitation). OPG completed an assessment to demonstrate that routine monitoring is not required for radionuclides in stormwater and foundation drainage. CNSC staff reviewed and accepted OPG's assessment. CNSC staff do not foresee OPG's licensing basis amendment request impacting the requirement for stormwater monitoring.

In 2020, as part of OPG's implementation of CSA Standard N288.7-15, *Groundwater Protection Programs at Class I Nuclear Facilities and Uranium Mines and Mills*, OPG established a groundwater protection program, which includes a groundwater monitoring program. The purpose of the groundwater monitoring program is to minimize or prevent releases and effects to groundwater, as well as to confirm that adequate measures are in place to control and/or monitor these releases. CNSC staff conclude that there will be no foreseen adverse effects to groundwater protection as a result of this proposed amendment.

Protection of People

This specific area within the environmental protection SCA is related to ensuring that members of the public are not exposed to "unreasonable" risk with respect to radiological and hazardous substances discharged from the facility.

Review of OPG's results of the environmental monitoring programs reports for the period of 2018-2022 shows that the concentration of radionuclides in the environment resulted in dose to the public that are well below regulatory limits.

The following table provides the doses to the public from the Pickering Site over the current licensing period:

Table 2: Dose to the public due to the concentration of radionuclides in the environment

DOSE TO A MEMBER OF THE PUBLIC[1]						
Dose Statistic	**2018**	**2019**	**2020**	**2021**	**2022**	**Regulatory Limit**
Maximum Effective Dose (mSv)	0.0021	0.0017	0.0012	0.0020	0.0019	1 mSv/year

1. OPG does not calculate individual public dose for PMWF. It calculates an annual site public dose which is reported annually in OPG's Annual Environmental Monitoring report

Hazardous substances releases at the facility are very low. DSC paint touch-up operations involve minimal paint quantities. Residual paint aerosols from the paint bays are removed through filters before exhausting to the active ventilation system and exhausted through a HEPA filter. Thus, the hazardous substance releases at the facility including the emissions from welding are very low. There have been no reported spills to the environment during the licence term. CNSC staff do not foresee OPG's licensing basis amendment request impacting the dose to public.

Environmental Risk Assessment

An Environmental Risk Assessment (ERA) is a systematic process used to identify, quantify, and characterize the risk posed by contaminants (radiological and non-radiological/chemical) and physical stressors in the environment on biological receptors. Receptors include humans and non-human biota. Human receptors are assessed through a human health risk assessment (HHRA) and non-human biota are addressed through an ecological risk assessment (EcoRA).

REGDOC 2.9.1 and CSA N288.6, *Environmental Risk Assessments at Nuclear Facilities and Uranium Mines and Mills* requires ERAs be updated every five years, or more frequently if facility changes are proposed which would trigger a predictive assessment. OPG completed its latest revision of its site wide Pickering ERA [10] as well as a revised Predictive Effects Assessment (PEA) [11] in 2022. CNSC staff reviewed OPG's application and the associated supporting documentation [3][4] and noted that OPG's inclusion of 6-year cooled fuel as part of the PWMF operations and its associated risk to the public and the environment is included in the most recent revision of the PEA for the Pickering site. The PEA covered the resulting predicted dose to the most exposed member of the public as well as the calculated doses to the ecological receptors. The resulting calculated doses were well below the regulatory limit for the dose of 1 mSv/y to the most exposed member of the public and the resulting doses to terrestrial/riparian organism were also well below the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) assessment benchmark.

Should the Commission authorize OPG's request, the licensee will integrate consideration of this project into the regular review of their site wide ERA, including results from the environmental monitoring program.

3.6.3 Summary

A summary of the licensee's past performance, challenges and proposed improvements are presented in the following subsections.

3.6.3.1 Past Performance

CNSC staff have assessed OPG's programs under the environmental protection SCA at the Pickering Site and conclude that during the licence term to date, OPG has met the applicable regulatory requirements.

3.6.3.2 Regulatory Focus

CNSC staff will continue to verify OPG performance and compliance in all aspects of the environmental protection SCA.

3.6.3.3 Proposed Improvements

There were no proposed improvements to the environmental protection program proposed in support of this amendment.

3.6.4 Conclusion

Based on CNSC staff's assessment of OPG's application, supporting documentation, and past performance, CNSC staff conclude that OPG has implemented and maintains an effective environmental protection program at the Pickering site that meets regulatory requirements.

3.7 Safeguards and Non-Proliferation

The Safeguards and Non-Proliferation SCA covers the programs and activities required for the successful implementation of obligations arising from the Canada/IAEA safeguards agreements as well as other measures arising from the *Treaty on the Non-Proliferation of Nuclear Weapons*.

The SpAs that comprise this SCA are:

- Nuclear material accountancy and control
- Access and assistance to the IAEA
- Operational and design information
- Safeguards equipment, containment and surveillance
- Import and export (requires separate authorization)

3.7.1 General Discussion

During the licensing period, CNSC staff conclude that OPG has implemented and maintained a safeguards program in accordance with the regulatory requirements.

3.7.2 Impact of OPG's proposal on Safeguards and Non-Proliferation SCA

As part of the safeguards approach at PWMF, the IAEA conducts gamma profiling and applies two independent containment measures to the DSCs to maintain continuity of knowledge in assuring that quantified amounts of nuclear material remain accounted for and have not been diverted. These containment measures include sealing of the DSC with a fiberoptic seal (COBRA) and either using the laser mapping for containment verification (LMCV) tool to perform a scan of the lid-to-base weld or applying a metal seal.

The processing and storage of minimum 6-year cooled fuel may have an impact on the existing IAEA safeguards containment approach. Based on OPG's conservative bounding scenario assumptions, the contact temperatures near the weld flange could reach 85 °C while the seal tubes within the DSC could exceed 100 °C. The current IAEA seals and equipment applied on the DSC are not designed for these temperatures and radiation fields. This may result in their damage and subsequent loss of the continuity of knowledge. In addition to potential damage to IAEA seals, the increased temperature of the DSC could also have an impact on IAEA inspectors' safety when performing safeguards activities on the DSCs (e.g., performing gamma profiling, weld scans and installing or changing seals).

There have been on-going discussions between the CNSC, the IAEA, and OPG on possible solutions to the higher temperature of the DSCs. OPG shared their OPEX from 1998, when an instrumented DSC (0024) was loaded with four full modules (384 bundles) of 6-year cooled fuel. This DSC was found to have temperature measurements much lower than OPG's conservative design analysis submitted for this current application. The maximum temperature for the outer liner was measured as 42.3 °C and the inner liner as 60.9 °C. The IAEA has indicated that its equipment and seals should not be impacted by temperatures below 70 °C.

The IAEA have agreed to support the OPG DSC commissioning test case to verify if the actual temperatures will be similar to the calculated temperatures or the measured temperatures in 1998. This will further be used to assess the impact on the current safeguards approach. OPG has proposed that these two to four DSCs be loaded with minimum 6-year cooled fuel, vacuum dried, and allowed to reach its equilibrium temperature within the view of the IAEA's surveillance camera. The IAEA will then be able to plan for – and if safe – perform their gamma profiling and sealing activities. The IAEA will assess whether there is any impact on their equipment, seals, or inspector safety for a period of time and will share the results with the CNSC. During the OPG commissioning test and IAEA assessment period, the DSCs must remain under IAEA surveillance in order to ensure continuity of knowledge of the nuclear material contained therein.

To support the commissioning test case, OPG should monitor and report to the CNSC the temperature and radiation levels for each surface that are in contact with the IAEA equipment and seals.

If it is determined that any of the existing safeguards measures will be negatively impacted by the higher radiation dose and temperature, the CNSC will coordinate with the IAEA and OPG to explore alternative safeguards measures and/or operational approaches. Should the exploration of such alternatives be required, OPG has proposed to reverse load the unwelded DSC until an approach is agreed upon. This process involves moving the DSC back to PNGS and unloading the 6-year cooled fuel back to the IFB-B.

CNSC staff is satisfied with OPG's proposed approach to evaluate the impact of the 6-year cooled fuel on IAEA equipment and seals during the commissioning test case and the safeguards options available depending on the outcome of the testing. It should be noted that any DSC must have dual IAEA containment and/or surveillance measures successfully applied before being moved out of IAEA's camera views in the waste management facility. CSNC staff will monitor this activity closely during the commissioning.

3.7.3 Summary

A summary of the licensee's past performance, challenges and proposed improvements are presented in the following subsections.

3.7.3.1 Past Performance

Nuclear material accountancy and control

The facility has complied with CNSC's regulatory requirements in accordance with REGDOC-2.13.1, *Safeguards and Nuclear Material Accountancy*. OPG has submitted the required monthly general ledgers, among other required forms, over the licence period.

Access and assistance to the IAEA

The facility has granted adequate access and assistance to the IAEA for safeguards activities during the licensing period.

During the licensing period, the IAEA performed inspections and verification activities, including 6 Physical Inventory Verifications (PIV), 6 Design Information Verifications (DIV), 16 Unannounced Inspections (UI), 36 Dry Storage Container (DSC) Sealings, and 1 Complementary Access (CA). In all cases, the facility provided the IAEA with the necessary access and assistance to perform the activities and complied with all regulatory requirements.

Year	Physical Inventory Verification (PIV)	Design Information Verification (DIV)	Unannounced Inspection (UI)	Complementary Access (CA)	Dry Storage Container (DSC) Sealing
2018	1	1	4	0	5
2019	1	1	1	0	8
2020	1	1	2	0	5
2021	1	1	3	0	5
2022	1	1	3	0	6
2023	1	1	3	1	7
Total	6	6	16	1	36

Operational and design information

During the licensing period, the licensee submitted its annual operational programs and Additional Protocol declarations, as well as quarterly updates to the operational program in a timely manner. The CNSC reviewed these documents and determined that they met requirements and expectations. OPG has provided revisions to their Design Information Questionnaire (DIQ) throughout the licensing period to reflect the safeguards-relevant changes to the facility and its safeguards program.

Safeguards equipment, containment and surveillance

During the licencing period, OPG provided the assistance required for the IAEA's safeguards equipment, containment, and surveillance activities.

Import and Export

The scope of the non-proliferation program is limited to the tracking and reporting of foreign obligations and origins of nuclear material. CNSC staff determined that OPG has complied with the CNSC's regulatory requirements in this respect.

The import and export of controlled nuclear substances, equipment and information identified in the *Nuclear Non-proliferation Import and Export Control Regulations* require separate authorization from the CNSC, consistent with section 3(2) of the *General Nuclear Safety and Control Regulations*.

3.7.3.2 Regulatory Focus

CNSC staff will continue to monitor OPG's performance in this SCA through regulatory oversight activities including participation in IAEA inspections, performance of CNSC evaluations, and ongoing assessments of compliance with reporting requirements.

3.7.3.3 Proposed Improvements

OPG and the CNSC continue to review the IAEA's equipment infrastructure requirements documents for the proposed equipment-based approach (EBA) for IAEA verification of spent fuel loadings and transfers from Pickering Nuclear Power Generating Station to PWMF. A series of technical meetings with the IAEA and OPG have been conducted and further discussions are to be planned in the future to resolve the remaining technical issues. The potential impact of the loading and transfer of 6-year cooled fuel will be assessed on the EBA after the proposed DSC commissioning test.

3.7.4 Conclusion

Based on CNSC staff's assessment of OPG's application, supporting documentation, and past performance, CNSC staff conclude that OPG will continue to implement and maintain a safeguards program in accordance with the regulatory requirements and potential impact resulting from the proposed application.

Should the Commission approve OPG's application, the CNSC, IAEA, and OPG will continue to work together to determine the potential impact of the DSCs with minimum 6-year cooled fuel on the current safeguards approach during the commissioning test. Revised safeguards measures and/or an alternative operational approach may be required depending on the results of the test and the IAEA's analysis. The CNSC will continue to ensure that Canada's safeguards obligations are met for the processing and storage of spent fuel.

3.8 Indigenous Consultation and Engagement

The duty to consult with Indigenous Nations and communities applies when the Crown contemplates actions that may adversely impact potential or established Indigenous and/or treaty rights. The CNSC ensures that all its licensing decisions under the NSCA uphold the honour of the Crown and consider Indigenous peoples' potential or established Indigenous and/or treaty rights pursuant to section 35 of the *Constitution Act, 1982*.

OPG's proposed change to the PWMF licensing basis does not involve any physical changes to the footprint of OPG's PWMF operations, and the impacts beyond the limits of the PWMF are expected to be negligible. Therefore, CNSC staff are of the opinion that this licensing decision is unlikely to have potential new impacts on Indigenous and/or treaty rights.

CNSC staff have informed and engaged with all interested Indigenous Nations and communities in relation to this licensing basis amendment application and encouraged them to identify any concerns and participate in the regulatory review process.

The CNSC also incorporates ongoing regulatory engagement with Indigenous Nations and communities into its daily activities as a life-cycle regulator. Indigenous engagement refers to efforts taken to build relationships with Indigenous Peoples regarding their concerns regarding regulatory activities and processes when the legal duty to consult is not raised. Such engagement activities allow CNSC to establish and maintain relationships with Indigenous Nations and communities early and on an on-going basis. Indigenous engagement activities may assist and inform the CNSC in meeting its future engagement obligations.

3.8.1.1 CNSC Staff Engagement Activities

CNSC staff have identified and engaged with the Indigenous Nations and communities who may have an interest in the application for a proposed change to licensing basis for its PWMF to process and store up to 100 DSCs containing 6-year cooled fuel.

These include the following Indigenous Nations and communities with established Indigenous and treaty rights to the lands and waters surrounding and inclusive of the PWMF:

- Alderville First Nation
- Curve Lake First Nation
- Hiawatha First Nation
- Mississaugas of Scugog Island First Nation
- Chippewas of Rama First Nation
- Chippewas of Georgina Island First Nation
- Beausoleil First Nation

CNSC staff also included the following Indigenous Nations and communities with interests in the PWMF and the lands and waters surrounding and inclusive of the PWMF:

- Six Nations
- Mohawks of the Bay of Quinte First Nation
- Métis Nation of Ontario

The CNSC is committed to ongoing engagement and long-term relationships with Indigenous Nations and communities with interest in CNSC's activities and processes. This engagement fosters discussion on specific projects and activities of potential interest or concern. The CNSC has signed Terms of Reference for long-term engagement with the Mississaugas of Scugog Island First Nation, Hiawatha First Nation, Curve Lake First Nation and the Métis Nation of Ontario to facilitate ongoing relationships and meaningful engagement and consultation. The CNSC is open to developing Terms of Reference for long-term engagement with other Indigenous Nations and communities as appropriate.

In December 2023, CNSC staff sent information about the CNSC's Participant Funding Program (PFP) funding opportunity specific to OPG's PWMF licensing basis amendment application to facilitate participation in the hearing process to all the Indigenous Nations and communities identified above. In January 2024, CNSC staff followed up with the Indigenous Nations and communities identified above to ensure they received notification of the upcoming hearing by email and provided an update on timelines and next steps in the regulatory review process including how to participate in the Commission hearing process. CNSC staff offered to set up information sessions and meetings regarding OPG's license application and encouraged Indigenous Nations and communities to participate in the regulatory review process and Commission hearing process through written interventions to advise the Commission directly of any concerns they may have in relation to this licensing amendment application, should they be interested.

To date, of the identified Indigenous Nations and communities, the Mississaugas of Scugog Island First Nation (MSIFN) and Hiawatha First Nation (HFN) have expressed specific interest in OPG's license application. MSIFN and HFN applied for funding through the CNSC's PFP to support their participation in the regulatory review and Commission hearing processes (further details in section 3.10). CNSC staff recognize that MSIFN has previously raised concerns regarding the PWMF and the storage of waste on-site and within their treaty and traditional territories. MSIFN and CNSC staff have had ongoing discussions regarding this concern throughout 2023, including an in-person meeting with MSIFN leadership in November 2023 in their community where OPG's PWMF licensing basis amendment application was discussed. CNSC staff and MSIFN continue to have discussions with regards to MSIFN's concerns that were raised regarding the increasing volume of CNSC-regulated activity within their territory. CNSC staff have committed to continue discussions with MSIFN regarding OPG's application in advance of the Commission hearing and collaborating with OPG and MSIFN to follow-up, respond to and address any questions or concerns raised regarding OPG's licensing basis amendment application for the PWMF.

In addition, CLFN and HFN have also expressed interest and concerns regarding the operations and activities at the PWMF and have expressed interest in further discussions with OPG and CNSC staff regarding this application, as well as other nuclear regulatory processes and projects taking place in Williams Treaties First Nations Territory. Similar to issues raised by MSIFN, CLFN and HFN have also indicated that the number of regulatory processes in their territory that they need to be informed of and participate in is a concern. Through regular meetings with CNSC staff, CLFN and HFN have indicated that they would like to have an in-depth meeting with CNSC subject matter experts regarding this proposed change to the licensing basis prior to the interventions' deadline for the Commission hearing. CNSC staff and HFN and CLFN discussed OPG's licensing basis amendment application for the PWMF with both Nations as part of in person meetings with community representatives and leadership in their respective communities in December 2023. In addition, CNSC staff are committed to having specific meetings and discussions with both HFN and CLFN to discuss any questions, comments, or concerns that they have. To date, CLFN and HFN have not raised specific concerns about this application, however, CNSC staff are committed to continuing to engage with and CLFN and HFN as part of the Terms of Reference for long-term engagement between CNSC staff and CLFN and HFN to ensure they receive up to date information regarding projects and activities of interest and have their questions and concerns addressed.

3.8.1.2 Licensee Engagement Activities

REGDOC-3.2.2, *Indigenous Engagement*, sets out requirements and guidance for licensees whose proposed projects may raise the Crown's duty to consult. While the CNSC cannot delegate its obligation, it can delegate procedural aspects of the consultation process to licensees, where appropriate. The information collected and measures proposed by licensees to avoid, mitigate, or offset potential adverse impacts from the proposed license amendment may be used by CNSC staff in meeting its consultation obligations.

OPG's application to change the licensing basis of the PWMF does not raise the formal requirements of REGDOC-3.2.2. However, OPG staff have provided the CNSC with an addendum to their application where they report their engagement activities specifically for this application and planned approach for continued engagement work moving forward.

CNSC staff have reviewed OPG's engagement activities for this licensing basis amendment, and after hearing concerns raised by Indigenous Nations and Communities, have spoken to OPG who have continued to take actions regarding ongoing communications and engagement with Indigenous Nations and Communities. If this engagement continues, CNSC will be satisfied with OPG's engagement activities to date. CNSC staff recognize that OPG has a well-established Indigenous engagement program and meets regularly with interested Indigenous Nations and communities to discuss topics in regularly scheduled meetings with Indigenous Nations and communities. OPG engages with Williams Treaties First Nations, Mohawks of the Bay of Quinte, and Métis Nation of Ontario (Region 8) on a regular basis. CNSC staff encourage OPG to continue engaging with these Indigenous Nations and communities regarding their facilities and activities including the licensing basis amendment application for the PWMF.

3.8.2 Conclusion

CNSC staff continue to engage with interested Indigenous Nations and communities regarding this licensing basis amendment application as well as other licence applications at OPG's nuclear sites. CNSC will continue to work collaboratively with each Nation and OPG to address their concerns, questions, and issues. In addition, CNSC staff encourages OPG to continue to engage with interested Indigenous Nations and communities on this application and other ongoing activities of interest. Finally, OPG is expected to keep CNSC staff informed of how key issues, questions and/or concerns raised, are being addressed as appropriate.

3.9 CNSC Public Disclosure, Consultation and Engagement

The NSCA mandates the CNSC to disseminate objective scientific, technical and regulatory information to the public concerning its activities and the activities it regulates. CNSC staff fulfill this mandate in a variety of ways, including hosting in-person and virtual information sessions and through annual regulatory reports.

In accordance with section 17 of the *Canadian Nuclear Safety Commission Rules of Procedure*, a Notice of Hearing in Writing has been issued and posted on the CNSC website inviting written comments and requests for appearances before the Commission.

CNSC staff continue to inform the public and Indigenous communities of our regulatory activities through regular website updates, publicly webcast Commission proceedings, social media, public webinars, mail drops and frequent discussion with key audiences near the facility. CNSC staff encourage the public and Indigenous communities to participate in the Commission's hearing in writing. The Participant Funding Program (PFP) was offered to assist interested members of the public, Indigenous peoples, and other stakeholders to prepare for and participate in the Commission's public hearing.

3.10 Licensee Public Information and Engagement

The CNSC requires licensees to maintain and implement public information and disclosure programs, in accordance with CNSC's REGDOC-3.2.1, *Public Information and Disclosure.* These programs are supported by disclosure protocols that outline the type of facility's information to be shared with the public as well as details on how that information is to be disseminated. This ensures that timely information about the health, safety and security of persons and the environment, and other issues associated with the lifecycle of nuclear facilities, is effectively communicated to the public.

CNSC staff monitor OPG's implementation of its public information and disclosure program to verify that it communicates regularly with its audiences in a way that is open, transparent, and meaningful to them.

3.10.1 Discussion

OPG has a public information and disclosure program which includes regular meetings with the Pickering Community Advisory Council (CAC), having a representative on the Durham Nuclear Health Committee (DNHC), and providing a community newsletter called "Neighbours" on a quarterly basis that is circulated by mail to residents throughout Durham Region (specific to the PWMF). This provides an update of activities and events that occur at the respective stations.

3.10.2 Conclusion

Through the methods listed above OPG provides an opportunity for public engagement and information exchange regarding the storage of minimum 6-year cooled fuel at PWMF. CNSC staff encourage OPG to continue to leverage their website and various social media platforms, conduct outreach and engagement with the public on this licensing basis amendment and other ongoing activities of interest at the PWMF.

3.11 Participant Funding Program

The CNSC made available up to $41,282.50 through its PFP to Indigenous Nations and Communities, members of the public and stakeholders in providing value-added information to the Commission through informed and topic-specific interventions. This funding was offered to review OPG's application and associated documents and to prepare written submissions for the Commission's hearing in writing. The deadline for applications was December 22, 2023.

3.11.1 Discussion

A Funding Review Committee (FRC), independent from CNSC staff, reviewed the funding applications received, and made recommendations on the allocation of funding to eligible applicants. Based on recommendations from the FRC, the CNSC awarded a total of $41,282.50 in funding to the following recipients, who are required to submit a written intervention to the Commission Secretariat by May 17, 2024, for the Commission's consideration:

- Mississaugas of Scugog First Nation
- Hiawatha First Nation
- Northwatch

3.11.2 Conclusion

The CNSC continues to actively promote ongoing communication and dissemination of regulatory and scientific information through social media channels, webinars, outreach in the local communities and postings on the CNSC web site. The CNSC has various mechanisms and processes such as the PFP and notifications on the CNSC website to encourage the public to participate in the Commission's hearing process, as described above. The CNSC has offered assistance to interested members of the public, Indigenous groups, and other stakeholders, through the PFP, to prepare for and participate in the Commission's hearing process.

4. Other Matters of Regulatory Interest

No other matters of regulatory interest are relevant to this CMD.

5. Overall Conclusions and Recommendations

CNSC staff's review of OPG's application and supporting documents concludes the following:

1. OPG has adequately assessed the hazards associated with licensed and proposed activities through safety assessments and demonstrated an adequate level of protection of the workers, the public, and the environment over a broad range of operating conditions.
2. OPG has demonstrated that the design considerations for processing and storing up to 100 DSCs with 6-year cooled fuel meet the regulatory requirements.
3. OPG remains qualified to carry on the activities authorized in the WFOL and continues to make provisions to protect workers, people, and the environment, and support Canada's international commitments to non-proliferation.

CNSC staff recommend that the Commission:

1. Amend the PWMF licensing basis to authorize OPG to process and store a maximum of 100 DSCs containing a minimum of 6-year cooled fuel at PWMF.

If the Commission accepts CNSC staff's recommendations,

a. CNSC staff will revise the PWMF LCH as specified in Part 2 of this submission.

References

[1] Pickering Nuclear Waste Facility: Waste Facility Operating Licence, February 6, 2018, e-Doc 5188230.

[2] Record of Decision – Application to Renew the Waste Facility Operating Licence for the Pickering Waste Management Facility, 2017-H04, e-Doc 5345395.

[3] OPG Letter, K. Aggarwal to D. Saumure, "OPG – Change Request Application for Amendment to the Pickering Waste Management Facility (PWMF) Waste Facility Operating Licence WFOL W4-350.00/2028", June 20, 2023, CD # 92896-CORR-00531-01478, e-Doc 7068976.

[4] OPG Letter, K. Aggarwal to M. Bacon-Dussault, "OPG - Addendum to the Application for Amendment to the Pickering Waste Management Facility, Waste Facility Operating Licence WFOL-W4-350.00/2028", December 22, 2023, CD # 92896-CORR-00531-01530, e-Doc 7203226.

[5] OPG, "Pickering Waste Management Facility – Safety Report", November 2018, CD# 92896-SR-01320-10002-R006, e-Doc 6329315. **(Protected B)**

[6] OPG Letter, K. Aggarwal to T. Kalindjian, "Response to CNSC Staff's Commitment Request Regarding DSC Commissioning in Respect of the Licensing Basis Amendment Application for Pickering Waste Management Facility Operating Licence W4-350.00/2028", February 14, 2024, CD# 92896-CORR-00531-01533 P, e-Doc 7222530.

[7] Pickering Waste Management Facility Licence Conditions Handbook: LCH-W4-350.00/2028, July 22, 2020, e-Doc 6344756.

[8] OPG Correspondence, C. Bhagan to N. Petseva, "CNSC Staff's Prior Written Notification of Document Changes: 92896-SR-01320- 10002, Nuclear Sustainability Services – Pickering Waste Management Facility Safety Report, R007", October 19, 2023, CD# 92896-CORR-00531-01487, e-Doc 7149349. **(Protected B)**

[9] OPG Letter, K. Aggarwal to T. Kalindjian, "OPG Response to CNSC Staff Comments on OPG's Proposal to Store Minimum 6-Year-Old Cooled Used Fuel at the Pickering Waste Management Facility", June 14, 2021, CD# 92896-CORR-00531-01430, e-Doc 6585972. **(Protected B)**

[10] OPG, Environmental Risk Assessment Report for Pickering Nuclear, P-REP-07701-00007 R001, March 31, 2023.

[11] OPG, Predictive Effects Assessment for Pickering Nuclear Safe Storage – 2022 Addendum Report, P-REP-07701-00006 R001, March 31, 2023.

Glossary

For definitions of terms used in this document, see *REGDOC-3.6, Glossary of CNSC Terminology*, which includes terms and definitions used in the *Nuclear Safety and Control Act* and the *Regulations* made under it, and in *CNSC regulatory documents* and other publications.

Additional terms and acronyms used in this CMD are listed below.

AIA	Authorized Inspection Agency
ALARA	As Low As Reasonably Achievable
CA	Complimentary Access
CAC	Community Advisory Council
CLFN	Curve Lake First Nation
CMD	Commission Member Document
CNSC	Canadian Nuclear Safety Commission
CSA	Canadian Standards Association
DIQ	Design Information Questionnaire
DIV	Design Information Verifications
DNHC	Durham Nuclear Health Committee
DSC	Dry Storage Container
DSM	Dry Storage Modules
EBA	Equipment-based Approach
ECC	Engineering Change Control
EcoRA	Ecological Risk Assessment
EMS	Environmental Management System
EPR	Environmental Protection Review
ERA	Environmental Risk Assessment
FRC	Funding Review Committee
HEPA	High Efficiency Particulate Air
HFN	Hiawatha First Nation
HHRA	Human Health Risk Assessment
IAA	*Impact Assessment Act*
IAEA	International Atomic Energy Agency
IFB	Irradiated Fuel Bay

LCH	Licence Conditions Handbook
MSIFN	Mississauga of Scugog Island First Nation
NEW	Nuclear Energy Worker
NSCA	*Nuclear Safety and Control Act*
OPEX	Operational Experience
OPG	Ontario Power Generation
PAUT	Phased Array Ultrasonic Testing
PEA	Predictive Effects Assessment
PFP	Participant Funding Program
PIV	Physical Inventory Verifications
PNGS	Pickering Nuclear Generating Station
PWMF	Pickering Waste Management Facility
RCSA	Retube Component Storage Area
SB	Storage Building
SCA	Safety and Control Area
SpA	Specific Area
SSC	Systems, Structures and Components
TSSA	Technical Standards and Safety Authority
UI	Unannounced Inspections
UNSCEAR	United Nations Scientific Committee on the Effects of Atomic Radiation
WFOL	Waste Facility Operating Licence

A. Basis for the Recommendation(s)

A.1 Detailed Summary of CNSC Assessment of Application

CNSC's staff assessment of OPG's application included a completeness check, a sufficiency check, and a technical assessment against regulatory requirements. The completeness check verified whether the application included the prescribed information in accordance with the *Nuclear Safety and Control Act* and applicable regulations. For all facilities (i.e., Class I and Class II facilities), it is important to consider and address all licence application requirements within the applicable CNSC regulations. As an application for an amendment of the licensing basis, OPG is subject to the requirements pursuant to section 6 of the *General Nuclear Safety and Control Regulations*.

The sufficiency check verified whether the application included sufficient and quality information for CNSC staff to conduct the technical assessment. The technical assessment verified whether the application included adequate safety and control measures to address CNSC requirements. Documents originally submitted as part of the application may have been revised, updated, or replaced over the course of the assessment to address CNSC requirements.

Pursuant to Section 3 of the *General Nuclear Safety and Control Regulations* **Licences – General Application Requirements**	**Location in Application or Supporting Document(s) as Noted by OPG**	**Complete?**	**Sufficient?**	**Adequate?**
(1) An application for a licence shall contain the following information:				
(a) the applicant's name and business address;	OPG's application, attachment 1, Licence Amendment Matrix – Applicable Regulations	Yes	Yes	Yes
(b) the activity to be licensed and its purpose;	OPG's application, attachment 1, Licence Amendment Matrix – Applicable Regulations	Yes	Yes	Yes
(c) the name, maximum quantity, and form of any nuclear substance to be encompassed by the licence;	OPG's application, attachment 1, Licence Amendment Matrix – Applicable Regulations	Yes	Yes	Yes

Pursuant to Section 3 of the *General Nuclear Safety and Control Regulations* Licences – General Application Requirements	Location in Application or Supporting Document(s) as Noted by OPG	Complete?	Sufficient?	Adequate?
(d) a description of any nuclear facility, prescribed equipment, or prescribed information to be encompassed by the licence;	OPG's application, Attachment 2, Licence Amendment Application for the Storage of Minimum 6-Year Cooled Fuel at Pickering Waste Management Facility	Yes	Yes	Yes
(e) the proposed measures to ensure compliance with the *Radiation Protection Regulations*, the *Nuclear Security Regulations* and the *Packaging and Transport of Nuclear Substances Regulations, 2015;*	OPG's application, Attachment 2, Licence Amendment Application for the Storage of Minimum 6-Year Cooled Fuel at Pickering Waste Management Facility	Yes	Yes	Yes
(f) any proposed action level for the purpose of section 6 of the *Radiation Protection Regulations*;	OPG's application, attachment 1, Licence Amendment Matrix – Applicable Regulations	Yes	Yes	Yes
(g) the proposed measures to control access to the site of the activity to be licensed and the nuclear substance, prescribed equipment, or prescribed information;	OPG's application, attachment 1, Licence Amendment Matrix – Applicable Regulations	Yes	Yes	Yes
(h) the proposed measures to prevent loss or illegal use, possession, or removal of the nuclear substance, prescribed equipment, or prescribed information;	OPG's application, attachment 1, Licence Amendment Matrix – Applicable Regulations	Yes	Yes	Yes

Pursuant to Section 3 of the *General Nuclear Safety and Control Regulations* **Licences – General Application Requirements**	**Location in Application or Supporting Document(s) as Noted by OPG**	**Complete?**	**Sufficient?**	**Adequate?**
(i) a description and the results of any test, analysis or calculation performed to substantiate the information included in the application;	OPG's addendum, Attachment 2, Licence Amendment Application for the Storage of Minimum 6-Year Cooled Fuel at the Pickering Waste Management Facility	Yes	Yes	Yes
(j) the name, quantity, form, origin and volume of any radioactive waste or hazardous waste that may result from the activity to be licensed, including waste that may be stored, managed, processed, or disposed of at the site of the activity to be licensed, and the proposed method for managing and disposing of that waste;	OPG's application, attachment 1, Licence Amendment Matrix – Applicable Regulations	Yes	Yes	Yes
(k) the applicant's organizational management structure in so far as it may bear on the applicant's compliance with the [NSCA] and the Regulations made under it, including the internal allocation of functions, responsibilities and authority;	OPG's application, attachment 1, Licence Amendment Matrix – Applicable Regulations	Yes	Yes	Yes
(l) a description of any proposed financial guarantee relating to the activity to be licensed;	OPG's addendum, attachment 1, Licence Compliance Matrix – *Nuclear Safety Control Act* and Associated Regulations	Yes	Yes	Yes

Pursuant to Section 3 of the *General Nuclear Safety and Control Regulations* **Licences – General Application Requirements**	**Location in Application or Supporting Document(s) as Noted by OPG**	**Complete?**	**Sufficient?**	**Adequate?**
(m) any other information required by the [NSCA] or the regulations made under it for the activity to be licensed and the nuclear substance, nuclear facility, prescribed equipment or prescribed information to be encompassed by the licence.	OPG's application, attachment 1, 2, enclosures 1-4	Yes	Yes	Yes

A.2 Technical Basis

The technical basis for the recommendations presented in this CMD includes regulatory documents, national standards, and international guidance documents, and is specified in the applicable sections of the PWMF LCH.

B. Safety and Control Area Framework

B.1 Safety and Control Areas Defined

The safety and control areas identified in section 2.2 and discussed in summary in sections 3.1 through 3.7 are comprised of specific areas of regulatory interest which vary between facility types.

The following table provides a high-level definition of each SCA. The specific areas within each SCA are to be identified by the CMD preparation team in the respective areas within section 3 of this CMD.

SAFETY AND CONTROL AREA FRAMEWORK		
Functional Area	**Safety and Control Area**	**Definition**
Management	Operating Performance	Includes an overall review of the conduct of the licensed activities and the activities that enable effective performance.
Facility and Equipment	Safety Analysis	Covers maintenance of the safety analysis that supports that overall safety case for the facility. Safety analysis is a systematic evaluation of the potential hazards associated with the conduct of a proposed activity or facility and considers the effectiveness of preventive measures and strategies in reducing the effects of such hazards.
	Physical Design	Relates to activities that impact on the ability of systems, components and structures to meet and maintain their design basis given new information arising over time and taking changes in the external environment into account.
	Fitness for Service	Covers activities that impact on the physical condition of systems, components and structures to ensure that they remain effective over time. This area includes programs that ensure all equipment is available to perform its intended design function when called upon to do so.
Core Control Processes	Radiation Protection	Covers the implementation of a radiation protection program in accordance with the *Radiation Protection Regulations*. This program must ensure that contamination levels and radiation doses received by individuals are monitored and controlled and maintained ALARA.
	Environmental Protection	Covers programs that identify, control and monitor all releases of radioactive and hazardous substances and effects on the environment from facilities or as the result of licensed activities.

SAFETY AND CONTROL AREA FRAMEWORK		
Functional Area	**Safety and Control Area**	**Definition**
	Safeguards and Non-Proliferation	Covers the programs and activities required for the successful implementation of the obligations arising from the Canada/International Atomic Energy Agency (IAEA) safeguards agreements, as well as all other measures arising from the *Treaty on the Non-Proliferation of Nuclear Weapons*.

B.2 Specific Areas for this Facility Type

The following table identifies the specific areas that comprise each SCA for a waste management facility, as applicable for this application:

SPECIFIC AREAS FOR THIS FACILITY TYPE		
Functional Area	**Safety and Control Area**	**Specific Areas**
Management	Operating Performance	▪ Conduct of Licensed Activity ▪ Procedures ▪ Reporting and Trending
Facility and Equipment	Safety Analysis	▪ Deterministic Safety Analysis ▪ Hazard Analysis
	Physical Design	▪ Design Governance ▪ Structure Design ▪ System Design ▪ Components Design
	Fitness for Service	▪ Aging Management
Core Control Processes	Radiation Protection	▪ Application of ALARA ▪ Worker Dose Control ▪ Radiation Protection Program Performance ▪ Radiological Hazard Control
	Environmental Protection	▪ Effluent and Emissions Control (releases) ▪ Environmental Management System (EMS) ▪ Assessment and Monitoring ▪ Protection of People ▪ Environmental Risk Assessment
	Safeguards and Non-Proliferation	▪ Nuclear Material Accountancy and Control ▪ Access and Assistance to the IAEA ▪ Operational and Design Information ▪ Safeguards Equipment, Containment and Surveillance

PART 2

Part 2 of this CMD provides all relevant information pertaining directly to the licence, including:

The current licence; and

The draft licence conditions handbook.

Current Licence

e-Doc 5188230

Proposed Licence Changes

No change to the licence is being recommended.

PDF Ref.: e-Doc 5188230
Word Ref.: e-Doc 5156473
File/Dossier: 2.05

WASTE FACILITY OPERATING LICENCE

PICKERING WASTE MANAGEMENT FACILITY

I) LICENCE NUMBER: **WFOL-W4-350.00/2028**

II) LICENSEE: Pursuant to section 24 of the *Nuclear Safety and Control Act* this licence is issued to:

Ontario Power Generation Inc.
700 University Avenue
Toronto, Ontario
M5G 1X6

III) LICENCE PERIOD: This licence is valid from **April 1, 2018** to **August 31, 2028** unless suspended, amended, revoked, replaced, or transferred.

IV) LICENSED ACTIVITIES:

This licence authorizes the licensee to:

(i) operate the Pickering Waste Management Facility ("the facility") located at the Pickering Nuclear Generating Station, City of Pickering, Regional Municipality of Durham, Province of Ontario;

(ii) possess, transfer, use, process, package, manage, and store nuclear substances that are required for, associated with or arise from the activities described in (i);

(iii) transport Category II nuclear materials that are associated with the activities described in (i) on the site of the Pickering Nuclear Generating Station;

(iv) carry out the site preparation, construction, or construction modifications at the facility associated with the authorized additional processing and storage buildings, when on completion will result in a total of no more than 1 dry storage container processing building and no more than 6 used fuel dry storage buildings; and,

(v) possess and use prescribed equipment and prescribed information that are required for, associated with or arise from the activities described in (i), (ii), (iii), and (iv).

V) EXPLANATORY NOTES:

(i) Unless otherwise provided for in this licence, words and expressions used in this licence have the same meaning as in the *Nuclear Safety and Control Act* and associated Regulations.

(ii) The Pickering Waste Management Facility licence conditions handbook (LCH) provides compliance verification criteria used to meet the conditions of this licence. The LCH also provides information on delegation of authority and document version control.

VI) CONDITIONS:

G GENERAL

G.1 Licensing Basis for Licensed Activities

The licensee shall conduct the activities described in Part IV of this licence in accordance with the licensing basis, defined as:

(i) the regulatory requirements set out in the applicable laws and regulations;

(ii) the conditions and safety and control measures described in the facility's or activity's licence and the documents directly referenced in that licence;

(iii) the safety and control measures described in the licence application and the documents needed to support that licence application;

unless otherwise approved in writing by the Canadian Nuclear Safety Commission (hereinafter "the Commission").

G.2 Notification of Changes

The licensee shall give written notification of changes to the facility or its operation, including deviation from design, operating conditions, policies, programs and methods referred to in the licensing basis.

G.3 Financial Guarantee

The licensee shall maintain a financial guarantee for decommissioning that is acceptable to the Commission.

G.4 Public Information and Disclosure

The licensee shall implement and maintain a public information and disclosure program.

1 MANAGEMENT SYSTEM

1.1 Management System

The licensee shall implement and maintain a management system.

1.2 Management of Contractors

The licensee shall ensure that every contractor working at the facility complies with this licence.

2 HUMAN PERFORMANCE MANAGEMENT

2.1 Human Performance Program

The licensee shall implement and maintain a human performance program.

2.2 Training Program

The licensee shall implement and maintain a training program.

3 OPERATING PERFORMANCE

3.1 Operations Program

The licensee shall implement and maintain an operating program, which includes a set of operating limits.

3.2 Reporting Requirements

The licensee shall implement and maintain a program for reporting to the Commission or a person authorized by the Commission.

4 SAFETY ANALYSIS

4.1 Safety Analysis Program

The licensee shall implement and maintain a safety analysis program.

5 PHYSICAL DESIGN

5.1 Design Program

The licensee shall implement and maintain a design program.

5.2 Pressure Boundary

The licensee shall implement and maintain a pressure boundary program and have in place a formal agreement with an Authorized Inspection Agency.

6 FITNESS FOR SERVICE

6.1 Fitness for Service Program

The licensee shall implement and maintain a fitness for service program.

7 RADIATION PROTECTION

7.1 Radiation Protection

The licensee shall implement and maintain a radiation protection program, which includes a set of action levels. When the licensee becomes aware that an action level has been reached, the licensee shall notify the Commission within seven days.

8 CONVENTIONAL HEALTH AND SAFETY

8.1 Conventional Health and Safety Program

The licensee shall implement and maintain a conventional health and safety program.

9 ENVIRONMENTAL PROTECTION

9.1 Environmental Protection

The licensee shall implement and maintain an environmental protection program, which includes a set of action levels. When the licensee becomes aware that an action level has been reached, the licensee shall notify the Commission within seven days.

9.2 Environmental Assessment Follow-up Program

The licensee shall implement an environment assessment follow-up program.

10 EMERGENCY MANAGEMENT AND FIRE PROTECTION

10.1 Emergency Preparedness Program

The licensee shall implement and maintain an emergency preparedness program.

10.2 Fire Protection Program

The licensee shall implement and maintain a fire protection program.

11 WASTE MANAGEMENT

11.1 Waste Management Program

The licensee shall implement and maintain a waste management program.

11.2 Decommissioning Plan

The licensee shall maintain a decommissioning plan.

12 SECURITY

12.1 Security Program

The licensee shall implement and maintain a security program.

12.2 Construction

The licensee shall not carry out the activities referred to in paragraph (ii) of Part IV of this licence that relate to completed construction activities in paragraph (iv) of Part IV of this licence until the submission of the proposed security arrangements and measures for the new building, or any potential modifications to the protected area that may be associated with this new building, that is acceptable to the Commission or a person authorized by the Commission.

13 SAFEGUARDS AND NON-PROLIFERATION

13.1 Safeguards Program

The licensee shall implement and maintain a safeguards program.

14 PACKAGING AND TRANSPORT

14.1 Packaging and Transport Program

The licensee shall implement and maintain a packaging and transport program.

15 FACILITY-SPECIFIC

15.1 Construction Plans

The licensee shall submit an environmental management plan, a construction verification plan and the project design requirements prior to the commencement of construction activities described in paragraph (iv) of Part IV of this licence.

15.2 Commissioning Report

The licensee shall not carry out the activities referred to in paragraph (ii) of Part IV of this licence that relate to completed construction activities in paragraph (iv) of Part IV of this licence until the submission of a commissioning report that is acceptable to the Commission or a person authorized by the Commission.

SIGNED at OTTAWA, this 6th day of February, 2018

M. Binder

Michael Binder, President
On behalf of the Canadian Nuclear Safety Commission

Draft Licence Conditions Handbook

DRAFT LCH e-Doc 7254967

Canada's Nuclear Regulator

e-Doc 7254967 (Word)
e-Doc XXXXX (PDF)

DRAFT

LICENCE CONDITIONS HANDBOOK

LCH-W4-350.00/2028

Pickering Waste Management Facility

Waste Facility Operating Licence

WFOL-W4-350.00/2028

Revision 2

e-Doc 7254967 (Word)
e-Doc XXXXXX (PDF)

Canadian Nuclear Safety Commission

Commission canadienne de sûreté nucléaire

Canada

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Licence Conditions Handbook
LCH-W4-350.00/2028
Pickering Waste Management Facility
Waste Facility Operating Licence
WFOL-W4-350.00/2028

SIGNED at OTTAWA this ________day of __________________, 2024

____

Kimberley Campbell, Director
Wastes and Decommissioning Division
CANADIAN NUCLEAR SAFETY COMMISSION

e-Doc 7254967 (Word)
e-Doc XXXXX (PDF)

Revision History:

Effective Date	Revision	Word e-Doc and Version	Description of the Changes	Change Approval Form e-Doc
2018-06-12	R00	5156809 v6	Original document	N/A
2020-07-22	R01	5975449	Major changes to entire document. See 6266721	5975463
TBD	R02	7254967	Licensing basis amendment: • Licence Condition G1, Licensing Basis for licensed activities: add 92896-CORR-00531-01478 and 92896-CORR-00531-01530 P as licensee documents that do not require notification of change. • Licence condition 3.2, Reporting Requirements: add paragraph on Commissioning dry storage containers containing minimum 6-year cooled fuel. • Appendix D, List of Licensee documents that require notification of change: add 92896-CORR-00531-01478 and 92896-CORR-00531-01530 P	N/A

TABLE OF CONTENTS

INTRODUCTION

The general purpose of the Licence Conditions Handbook (LCH) is to identify and clarify the relevant parts of the licensing basis for each Licence Condition (LC). This will help ensure that the licensee maintains facility operation in accordance with the licensing basis for the facility and the intent of the licence. The LCH should be read in conjunction with the licence.

The LCH typically has three parts under each LC: the Preamble, Compliance Verification Criteria (CVC), and Guidance. The Preamble explains, as needed, the regulatory context, background, and/or history related to the LC. CVC are criteria used by Canadian Nuclear Safety Commission (CNSC) staff to verify and oversee compliance with the LC. Guidance is non-mandatory information, including direction, on how to comply with the LC.

Current versions of licensee documents listed in this LCH are recorded in e-Doc 5158818, which is controlled by the Wastes and Decommissioning Division (WDD) of the CNSC and is available to the licensee upon request.

This LCH has the following appendices:

- APPENDIX A, which describes the change control process;
- APPENDIX B, which includes a list of definitions and acronyms used in this LCH;
- APPENDIX C, which includes a list of licensing basis publications referenced in this LCH;
- APPENDIX D, which includes a list of licensee documents that require notification of change; and,
- APPENDIX E, which includes a list of guidance publications referenced in this LCH.

GENERAL

Licence Condition G.1 Licensing Basis for Licensed Activities

The licensee shall conduct the activities described in Part IV of this licence in accordance with the licensing basis, defined as:

(i) the regulatory requirements set out in the applicable laws and regulations;

(ii) the conditions and safety and control measures described in the facility's or activity's licence and the documents directly referenced in that licence;

(iii) the safety and control measures described in the licence application and the documents needed to support that licence application;

unless otherwise approved in writing by the Canadian Nuclear Safety Commission (hereinafter "the Commission").

Preamble

The licensing basis is discussed in REGDOC 3.5.3, *Regulatory Fundamentals.*

The standardized LCs, organized by Safety and Control Area (SCA), apply to all the licensed activities. Specific LCs were added for nuclear facility-specific activities, if required.

Compliance Verification Criteria

Licensee Documents that Require Notification of Change

Doc #	Title	Prior Notice
92896-CORR-00531-01031	Application for Renewal of Pickering Waste Management Facility Operating Licence	N
92896-CORR-00531-01075	Additional Information to Support the Application for Renewal of Pickering Waste Management Facility Operating Licence	N
92896-CORR-00531-01478	Change Request Application for Amendment to the Pickering Waste Management Facility (PWMF) Waste Facility Operating Licence WFOL W4-350.00/2028	N
92896-CORR-00531-01530 P	OPG - Addendum to the Application for Amendment to the Pickering Waste Management Facility, Waste Facility Operating Licence WFOL-W4-350.00/2028	N

Part (i) of the licensing basis includes, but is not limited to, the following.

- *Nuclear Safety Control Act*
- *Canadian Environmental Assessment Act*
- *Canadian Environmental Protection Act*

- *Nuclear Liability and Compensation Act*
- *Transportation of Dangerous Goods Act*
- *Access to Information Act*
- Canada/International Atomic Energy Agency (IAEA) Safeguards Agreement

The safety and control measures mentioned in the LC under Parts (ii) and (iii) of the licensing basis include important aspects of analysis, design, operation, etc. They may be found in high-level programmatic licensee documents but might also be found in lower-level, supporting documentation. They also include safety and control measures in licensing basis publications (e.g., CNSC REGDOC or Canadian Standards Association (CSA) Group standards) that are cited in the licence, the application, or in the licensee's supporting documentation.

Licensing basis publications are listed in tables in this LCH under the most relevant LC. All "shall" or normative statements in licensing basis publications are considered CVC unless stated otherwise. If any "should" or informative statements in licensing basis publications are also considered CVC, this is also explained under the most relevant LC.

The licensee documents in question, as well as the relevant licensing basis publications, may cite other documents that also contain safety and control measures (i.e., there may be safety and control measures in "nested" references). There is no predetermined limit to the degree of nesting at which relevant safety and control measures may be found.

LC G.1 requires the licensee to conform to, and/or implement, all the safety and control measures. Note, however, that not all details in referenced documents are necessarily considered to be safety and control measures.

- Details that are not directly relevant to safety and control measures for facilities or activities authorized by the licence are excluded from the licensing basis.
- Details that are relevant to a different SCA (i.e., not the one associated with the main document), are only part of the licensing basis to the extent that they are consistent with the main requirements for both SCAs.

The licensing basis is established by the Commission at the time the licence is issued. Per LC G.1, operation during the licence period that is not in accordance with the licensing basis is only allowed based on the written approval of the Commission. Similarly, only the Commission can change the licensing basis during the licence period; and this would also be expected to be recorded in writing.

In the event of any perceived or real conflict or inconsistency between two elements of the licensing basis, the licensee shall consult CNSC staff to determine the approach to resolve the issue.

This LC is not intended to unduly inhibit the ongoing management and operation of the facility or the licensee's ability to adapt to changing circumstances and continuously improve, in accordance with its management system. Where the licensing basis refers to specific configurations, methods, solutions, designs, etc., the licensee is free to propose alternate approaches as long as they remain, overall, in accordance with the licensing basis and have a neutral or positive impact on health, safety, the environment, security, and safeguards. However, the licensee shall assess changes to confirm that operations remain in accordance with the licensing basis.

Changes to certain licensee documents require written notification to the CNSC, even if they are in accordance with the licensing basis. Further information on this topic is provided under LC G.2.

For unapproved operation that is not in accordance with the licensing basis, the licensee shall take action as soon as practicable to return to a state consistent with the licensing basis, taking into account the risk significance of the situation.

In the event that the Commission grants approval to operate in a manner that is not in accordance with the existing licensing basis, this would effectively revise the licensing basis for the facility. The appropriate changes would be reflected in the CVC of the relevant LC.

Guidance

When the licensee becomes aware that a proposed change or activity might not be in accordance with the licensing basis, it should first seek direction from CNSC staff regarding the potential acceptability of this change or activity. The licensee should take into account that certain types of proposed changes might require significant lead times before CNSC staff can make recommendations and/or the Commission can properly consider them. Guidance for notifications to CNSC related to licensee changes are discussed under LC G.2.

Licence Condition G.2 Notification of Changes

> The licensee shall give written notification of changes to the facility or its operation, including deviation from design, operating conditions, policies, programs and methods referred to in the licensing basis.

Preamble

CNSC staff tracks, in e-Doc 5158818, the version history of licensee documents that require notification of change (with the exception of security-related documents).

Licensee documents tabulated in the CVC of the LCH are subdivided into groups having different requirements for notification of change – ones that require prior written notification of changes and those that require written notification only. For the former type, the licensee shall submit the document to the CNSC prior to implementing the change. Typically, the requirement is to submit the proposed changes 30 days prior to planned implementation; however, the licensee shall allow sufficient time for the CNSC to review the change proportionate to its complexity and the importance of the safety and control measures being affected. For the latter type, the licensee need only submit the document at the time of implementing the change.

Compliance Verification Criteria

Licensee Documents that Require Notification of Change

Doc #	Title	Prior Notice
OPG-PROG-0001	Information Management	N
OPG-PROC-0019	Records and Document Management	N

Written notification is a physical or electronic communication from a person authorized to act on behalf of the licensee to a CNSC delegated authority or a CNSC staff member acting on behalf of a CNSC delegated authority.

In general, the changes for which the licensee shall notify the CNSC are captured as changes to specific licensee documents. The LCH identifies them under the most relevant LC. However, the licensee documents identified in the LCH only represent the minimum subset of documents that require notification of change. For any change that is not captured as a change to a document identified in the LCH, if it negatively impacts designs, operating conditions, policies, programs, methods, or other elements that are integral to the licensing basis, the licensee shall provide written notification of the change. For example, if a licensee document in the CVC refers to another document, including a third-party document, without citing the revision number of that document, if that document changes and the licensee uses the revised version, the licensee shall determine if it is necessary to notify the CNSC of the change.

The documents needed to support the licence application may include documents produced by third parties (e.g., reports prepared by third party contractors). Changes to these documents require written notification to the CNSC only if the new version continues to form part of the licensing basis. That is, if the licensee implements a new version of a document prepared by a third party, it shall inform the CNSC of the change(s), per LC G.2. On the other hand, if a third party has updated a certain document, but the licensee has not adopted the new version as part of its safety and control measures, the licensee is not required to inform the CNSC that the third party has changed the document.

Licensee documents tabulated in the CVC of the LCH are subdivided into groups having different requirements for notification of change – ones that require prior written notification of changes and those that require written notification only. For the former type, the licensee shall submit the document to the CNSC prior to implementing the change. Typically, the requirement is to submit the proposed changes 30 days prior to planned implementation; however, the licensee shall allow sufficient time for the CNSC to review the change proportionate to its complexity and the importance of the safety and control measures being affected. For the latter type, the licensee need only submit the document at the time of implementing the change.

Changes to the licensing basis that are not clearly in a safe direction require further assessment of impact to determine if prior Commission approval is required in accordance with LC G.1. Additional considerations for changes to facility operation or operating limits, conditions or procedures are discussed under LC 3.1 and those for facility design or equipment are discussed under LC 5.1

If the licensee document, or some part of it, also requires CNSC acceptance of change, a footnote has been added to the table. Such a requirement may be established in the document itself, in another LC, or in a licensing basis publication.

Written notifications shall include a summary description of the change, the rationale for the change, expected duration (if not a permanent change), and a summary explanation of how the licensee has concluded that the change remains in accordance with the licensing basis (e.g., an evaluation of the impact on health, safety, security, the environment and Canada's international obligations). A copy of the revised written notification document shall accompany the notification. All written notifications shall be transmitted to CNSC per established communications protocols.

The above also applies to a notice of change that requires CNSC staff acceptance, due to some other requirement in the licensing basis.

Changes that are not clearly in the safe direction require further assessment of impact to determine if Commission approval is required in accordance with LC G.1.

The licensee shall notify the CNSC in writing when it plans to implement a new licensing basis publication, including the date by which implementation of the publication will be complete. The notice shall indicate the corresponding changes to licensee documents listed in the CVC of the LCH.

Guidance

A list of criteria that could help determine if a change would be in accordance with the licensing basis is provided in Appendix A of e-Doc 4055483*, Assessing licensee changes to documents or operations*. Such criteria would also be used if the change requires CNSC staff acceptance, due to some other requirement in the licensing basis.

For proposed changes that would not be in accordance with the licensing basis, the Guidance for LC G.1 applies.

Licence Condition G.3 Financial Guarantee

The licensee shall maintain a financial guarantee for decommissioning that is acceptable to the Commission.

Preamble

The licensee is responsible for all costs of implementing the proposed decommissioning plan (see LC 11.2) and providing an appropriate financial guarantee that is acceptable to the Commission.

Ontario Power Generation Inc. (OPG) maintains a consolidated financial guarantee to cover the future decommissioning of all of its Ontario based Class I and waste nuclear substance licence facilities, and the long-term management of used fuel and all other radioactive waste. The current financial guarantee for OPG was accepted by the Commission on November 27, 2017. The financial guarantee and the associated decommissioning plans are required to be revised by OPG every five years or when requested by the Commission. The acceptance of the proposed financial guarantee is a subject of a separate Commission proceeding not related to the licence renewal process. The OPG consolidated financial guarantee includes:

1. Access to the Ontario Nuclear Funds Agreement (ONFA) segregated funds pursuant to the CNSC Financial Security and ONFA Access Agreement between OPG, the Province of Ontario, and the CNSC effective January 1, 2018 to December 31, 2022; and,
2. A trust fund for the management of used fuel established pursuant to the *Nuclear Fuel Waste Act*.

Compliance Verification Criteria

Licensee Documents that Require Notification of Change

Org	Doc #	Title	Prior Notice
Joint	N/A	CNSC Financial Security and ONFA Access Agreement between OPG, the Province of Ontario and the CNSC effective January 1, 2018	Y[1]

Note: [1]Requires CNSC acceptance of change.

Licensing Basis Publications

Org	Doc #	Title	Version	Effective Date
CSA Group	N294-09	Decommissioning of facilities containing nuclear substances	2009	Implemented
CSA Group	N294-19	Decommissioning of facilities containing nuclear substances	2019	See Transition

The financial guarantee for decommissioning the nuclear facility shall be reviewed and revised by the licensee every five years, or when the Commission requires, or following a revision of the preliminary decommissioning plan (PDP) that significantly impacts the financial guarantee.

The next full update to the five-year reference plan for financial guarantee purposes is expected in 2022.

The licensee shall submit annually to the Commission a written report confirming that the financial guarantee for decommissioning costs remains valid, in effect, and sufficient to meet the decommissioning needs. The licensee shall submit this report by the end of February of each year, or at any time as the Commission may request.

Transition

The licensee shall implement the requirements of CSA Group standard N 294-19, *Decommissioning of Facilities Containing Nuclear Substances* for the next scheduled FG revision due to the CNSC in 2022.

Guidance

Guidance Publications

Org	Doc #	Title
CNSC	G-219	Decommissioning Planning for Licensed Activities
CNSC	G-206	Financial Guarantees for the Decommissioning of Licensed Activities

Licence Condition G.4 Public Information and Disclosure

The licensee shall implement and maintain a public information and disclosure program.

Preamble

A public information and disclosure program (PIDP) is a regulatory requirement for licence applicants and licensees under the *Class I Nuclear Facilities Regulations*, paragraph 3(j), which requires that a licence application contain a description of a program to inform persons living in the vicinity of the site of the general nature and characteristics of the anticipated effects on the environment, health and safety of persons.

The primary goal of the PIDP, as it relates to the licensed activities, is to ensure that information related to the health, safety and security of persons and the environment, and other issues associated with the life cycle of nuclear facilities are effectively communicated to the public.

Compliance Verification Criteria

Licensee Documents that Require Notification of Change

Doc #	Title	Prior Notice
N-STD-AS-0013	Nuclear Public Information Disclosure	N

Licensing Basis Publications

Org	Doc #	Title	Version	Effective Date
CNSC	RD/GD-99.3	Public Information and Disclosure	2012	Implemented
CNSC	REGDOC 3.2.1	Public Information and Disclosure	2018	TBD

The PIDP shall include a commitment to and disclosure protocol for ongoing timely communication of information related to the licensed facility during the course of the licence period.

Transition

The licensee shall provide a gap analysis and implementation plan for the requirements of REGDOC-3.2.1, *Public Information and Disclosure*, by August 7, 2020.

Guidance

None provided.

SCA – MANAGEMENT SYSTEM

Licence Condition 1.1 Management System

The licensee shall implement and maintain a management system.

Preamble

The management system must satisfy the requirements set out in the regulations made pursuant to the NSCA, the licence and the measures necessary to ensure that safety is of paramount consideration in implementation of the management system. An adequately established and implemented management system for a waste facility provides CNSC staff confidence and evidence that the licensing basis remains valid.

Compliance Verification Criteria

Licensee Documents that Require Notification of Change

Doc #	Title	Prior Notice
OPG-PROG-0009	Items and Services Management	N
OPG-PROG-0010	Health and Safety Management System Program	N
N-STD-AS-0020	Nuclear Management Systems Organizations	N
N-PROC-AS-0077	Nuclear Safety Culture Assessment	N
N-STD-AS-0023	Nuclear Safety Oversight	N
N-POL-0001	Nuclear Safety Policy	N
N-CHAR-AS-0002	Nuclear Management System	Y

Licensing Basis Publications

Org	Document #	Title	Version	Effective Date
CSA	N286	Management system requirements for nuclear facilities	2012	Implemented

Guidance

Additional information can be found in CNSC regulatory document REGDOC-2.1.1, *Management System*

Licence Condition 1.2 Management of Contractors

The licensee shall ensure that every contractor working at the facility complies with this licence.

Preamble

This LC requires that the licensee retain responsibility for the protection of the health, safety, and security of the public and workers, and the protection of environment when contractors perform licensed activities.

Compliance Verification Criteria

The management of contractors will be evaluated against the following elements and principles:

- the risks to contractors and risks to the organization from the use of contractors are evaluated to identify, assess, and eliminate or control hazards;
- contractors are adequately trained in up-to-date procedures and are qualified and competent (i.e., education, certification, designation, training, knowledge, skills, experience, abilities, and attitudes) to conduct work within the licensed facility; and,
- work carried out by the contractor is approved by competent members of the licensee's staff and monitored by qualified personnel.

As defined by the *General Nuclear Safety and Control Regulations*, workers include contractors and temporary employees who perform work that is referred in the licence. Although contractors may perform certain licensed activities in these circumstances, OPG retains the responsibility that the facility remains compliant with the licence. As such, OPG is accountable to the CNSC to provide the required assurances that the health, safety, and security of the public and workers, and the environment are protected. This accountability to the CNSC cannot be delegated through contractual arrangements.

Guidance

None provided.

SCA – HUMAN PERFORMANCE MANAGEMENT

Licence Condition 2.1 Human Performance Program

The licensee shall implement and maintain a human performance program.

Preamble

Paragraph 3(d)(1) of the *Class I Nuclear Facilities Regulations* requires that a licence application contain the proposed human performance program for the activity to be licensed, including measures to ensure workers' fitness for duty.

It is important that the licensee continuously monitors human performance, takes steps to identify human performance weaknesses and mechanisms that will improve human performance and reduce the likelihood of nuclear safety events that are attributable to human performance.

Human factors are factors that influence human performance as it relates to the safety of a nuclear facility or activity over all design and operations phases. These factors may include the characteristics of a person, task, equipment, organization, environment, and training. The consideration of human factors in issues such as interface design, training, procedures, and organization and job design may affect the reliability of humans performing tasks under various conditions.

Compliance Verification Criteria

Licensee Documents that Require Notification of Change

Doc #	Title	Prior Notice
N-PROG-AS-0002	Human Performance	N
N-PROC-OP-0047	Hours Of Work Limits and Managing Worker Fatigue	Y

Licensing Basis Publications

Org	Document #	Title	Version	Effective Date
CNSC	REGDOC-2.2.4	Fitness for Duty: Managing Worker Fatigue	2017	Implemented
CNSC	REGDOC-2.2.4	Fitness for Duty, Volume II: Managing Alcohol and Drug Use, version 2	2017	See Transition
CNSC	REGDOC-2.1.2	Safety Culture	2018	November 26, 2020*

*OPG has implemented REGDOC-2.1.2, with the exception of nuclear security culture. OPG has committed to revise its governance to include nuclear security culture by November 26, 2020

Sections 4.5.2, 4.12, and 9.9.2 of CSA Group standard N286-12, *Management System Requirements for Nuclear Facilities* contain requirements for the management system to support excellence in worker performance.

Transition

With the exception of random alcohol and drug testing requirements, implementation of REGDOC-2.2.4, *Fitness for Duty, Volume II: Managing Alcohol and Drug Use* will be six months from the date of Commission approval and subsequent publication of REGDOC-2.2.4 Volume II, version 3. Implementation of random alcohol and drug testing component will be 12 months from the date of Commission approval and subsequent publication of REGDOC-2.2.4 Volume II, version 3. [Reference e-Doc 5865465]

Guidance

Guidance Publications

Org	Doc #	Title
CNSC	G-276	Human Factors Engineering Program Plans
CNSC	G-278	Human Factors Verification and Validation Plans
CNSC	REGDOC-2.2.5	Minimum Staff Complement
CNSC	REGDOC-2.2.1	Human Factors

Licensees should implement a program that continuously monitors human performance, takes steps to identify human performance weaknesses, improves human performance, and reduces the likelihood of human performance related causes and root causes of nuclear safety events.

The human performance program should address and integrate the range of human factors that influence human performance, which include, but may not be limited to the following:

- the provision of qualified staff;
- the reduction of human error;
- organizational support for safe work activities; and,
- the continuous improvement of human performance.

Licence Condition 2.2 Training Program

The licensee shall implement and maintain a training program.

Preamble

Paragraphs 12(1)(a) and 12(1)(b) of the *General Nuclear Safety and Control Regulations* require that licensees ensure that workers are trained and qualified to carry on the licensed activity safely.

Compliance Verification Criteria

Licensee Documents that Require Notification of Change

Doc #	Title	Prior Notice
N-PROC-TR-0008	Systematic Approach to Training	N
N-PROG-TR-0005	Training	N

Licensing Basis Publications

Org	Doc #	Title	Version	Effective Date
CNSC	REGDOC-2.2.2	Personnel Training	2016	Implemented

The licensee shall implement and maintain training programs for workers in accordance with CNSC regulatory document REGDOC-2.2.2, *Personnel Training*

Guidance

None provided.

SCA – OPERATING PERFORMANCE

Licence Condition 3.1 Operating Performance

The licensee shall implement and maintain an operating program, which includes a set of operating limits.

Preamble

None provided.

Compliance Verification Criteria

Licensee Documents that Require Notification of Change

Doc #	Title	Prior Notice
92896-CORR-00531-01031	Application for Renewal of Pickering Waste Management Facility Operating Licence	N
92896-CORR-00531-01075	Additional Information to Support the Application for Renewal of Pickering Waste Management Facility Operating Licence	N
W-PROG-WM-0001	Nuclear Waste Management	Y
92896-OPP-01911.1-00001	Operating Policies and Principles, Pickering Waste Management Facility	Y
92896-SR-01320-10002	Pickering Waste Management Facility – Safety Report	Y

This LC requires that OPG implement and maintain operating policies, programs, and procedures. These include:

- define the operating rules consistent with the safety report and other licensing support documentation within which the facility will be operated, maintained, and modified, all of which should ensure nuclear safety;
- specify the authorities of facility staff to make decisions within the defined boundaries; and,
- identify and differentiate between actions where discretion may be applied and where jurisdictional authorization is required.

OPG shall ensure that procedures are current, periodically reviewed and updated, and complied with at all times.

Guidance

None provided.

Licence Condition 3.2 Reporting Requirements

The licensee shall implement and maintain a program for reporting to the Commission or a person authorized by the Commission.

Preamble

This LC requires the licensee to implement and maintain a process for reporting information to the CNSC. This includes monitoring results, changes to facilities or approved activities, performance assessments and the occurrence of unusual events. Sections 29 and 30 of the *General Nuclear Safety and Control Regulations* provides further insight into reportable events.

Compliance Verification Criteria

Licensee Documents that Require Notification of Change

Doc #	Title	Prior Notice
N-PROG-RA-0002	Conduct of Regulatory Affairs	N
N-PROG-RA-0003	Performance Improvement	N
N-PROC-RA-0020	Preliminary Event Notification	N
92896-OPP-01911.1-00001	Operating Policies and Principles, Pickering Waste Management Facility	Y

Licensing Basis Publications

Org	Doc #	Title	Version	Effective Date
CNSC	RD/GD-99.3	Public Information and Disclosure	2012	Implemented
CNSC	REGDOC-3.2.1	Public Information and Disclosure	2018	TBD
CNSC	REGDOC 3.1.2	Reporting Requirements, Volume 1: Non-Power Reactor Class I Nuclear Facilities and Uranium Mines and Mills	2018	Implemented

CNSC staff will verify that OPG submits a written report within 90 days of the end of each calendar year quarter on the operations of the Pickering Waste Management Facility (PWMF) and an annual written report to the CNSC within 90 days of the end of the calendar year that summarizes the information submitted in their quarterly reports.

The quarterly reports should include the information outlined in REGDOC 3.1.2, at a minimum:

- the principal licensed activities completed;
- the results of OPG's monitoring programs;

- a summary description of events reported to the Commission pursuant to sections 29 and 30 of the *General Nuclear Safety and Control Regulations*;
- a summary description of any changes in the methods, procedures, and equipment used to carry out the licensed activities, and any modifications made to the facility;
- information concerning implementation of their public disclosure protocol associated with CNSC regulatory/guidance document RD/GD-99.3, *Public Information and Disclosure*; and,
- a trending analysis of operational performance.

Commissioning dry storage containers containing minimum 6-year cooled fuel

Pursuant to e-Doc 7222530, the licensee has committed to providing dose rates and temperature measurements for both the weld surface and seal tube collected during commissioning of 2 to 4 dry storage containers containing 6-year cooled fuel with a comparison to predictions to CNSC staff no later than 30 days following the collection of data.

The licensee shall not proceed to the processing of DSCs loaded with less than 10-year cooled fuel until CNSC staff have reviewed the results of commissioning and conclude that the results are acceptable. This conclusion will be provided as a formal letter sent to OPG from CNSC staff.

Transition

The licensee shall provide a gap analysis and implementation plan for the requirements of REGDOC-3.2.1, *Public Information and Disclosure*, by August 7, 2020.

Guidance

For the purposes of efficiency, the annual report submission may be submitted with, and as a separate section of, the fourth quarterly operations report.

SCA – SAFETY ANALYSIS

Licence Condition 4.1 Safety Analysis Program

The licensee shall implement and maintain a safety analysis program.

Preamble

None provided.

Compliance Verification Criteria

Licensee Documents that Require Notification of Change

Doc #	Title	Prior Notice
N-PROG-MP-0014	Reactor Safety Program	N
92896-SR-01320-10002	Pickering Waste Management Facility – Safety Report	Y

Licensing Basis Publications

Org	Doc #	Title	Version	Effective Date
CSA Group	N292.0	General principles for the management of radioactive waste and irradiated fuel	2014	Implemented
CSA Group	N292.2	Interim dry storage of irradiated fuel	2013	Implemented
CSA Group	N292.3	Management of low- and intermediate-level radioactive waste	2014	Implemented
CSA Group	N286.7	Quality assurance of analytical, scientific, and design computer programs	2016	TBD

The safety analysis report is to confirm that the consequences of a range of events are acceptable. It includes an integrated assessment of the facility to demonstrate, among other things, adequate safety for external events such as fires, floods, and tornados, and adequate protective features to ensure the effects of an event do not impair safety-related systems, structures, and components (SSC).

Every five years, OPG shall submit a revised safety analysis report for the facility. CNSC staff review the safety analysis report to verify that OPG employs appropriate assumptions, applies adequate scope, and demonstrates acceptable results. The safety analysis report must demonstrate that the radiological consequences of accident scenarios do not exceed public dose limits.

Licensees shall carry out safety analyses to confirm that facility design changes will not result in a reduction of safety compared to the licensing basis, as per LC G.1. The safety analysis report shall:

- demonstrate compliance with public dose limits, the dose-related criteria, structural-integrity-related criteria, the limits on process and safety parameters, and safety or safety-related system requirements;
- justify appropriateness of the technical solutions employed in the supporting justification of safety requirements; and,
- complement other analyses and evaluations in defining a complete set of design and operating requirements.

OPG is expected to provide periodic updates to the report as needed or when there are major facility changes. The current safety analysis report for the PWMF was submitted to CNSC staff in 2018. The revised safety analysis report is due to be submitted to CNSC staff in 2023.

Transition

The licensee shall provide a gap analysis and implementation plan for the requirements CSA N286.7-16, *Quality Assurance of Analytical, Scientific, and Design Computer Programs*, by March 31, 2021

Guidance

None provided.

SCA – PHYSICAL DESIGN

Licence Condition 5.1 Design Program

The licensee shall implement and maintain a design program.

Preamble

None provided.

Compliance Verification Criteria

Licensee Documents that Require Notification of Change

Doc #	Title	Prior Notice
N-STD-MP-0028	Conduct of Engineering	N
N-STD-MP-0027	Configuration Management	N
N-PROG-MP-0009	Design Management	N
N-PROG-MP-0001	Engineering Change Control	N

Licensing Basis Publications

Org	Doc #	Title	Version	Effective Date
CSA Group	N393	Fire protection for facilities that process, handle, or store nuclear substances	2013	Implemented
NRC	N/A	National Building Code of Canada (2015)	2015	TBD
NRC	N/A	National Fire Code of Canada (2015)	2015	TBD

The licensee shall ensure that facility design and changes to facility design are accurately reflected in the safety analysis. Furthermore, the licensee shall ensure that facility status changes are controlled such that the facility is maintained and modified within the limits prescribed by the design basis and the licensing basis. Where the standards in those bases require specific reports, these shall be submitted to the CNSC.

The design of the nuclear facility and any modification shall comply with applicable codes, standards, and regulations including adequate consideration for human factors. For all current designs, the licensee shall modify and otherwise carry out work related to the nuclear facility in compliance with the applicable versions of the National Research Council Canada (NRC) *National Building Code of Canada* and the NRC *National Fire Code of Canada.*

The licensee shall, prior to implementing any proposed modification to the facility with the potential to impact protection from fire: arrange for a third-party review of the proposed modification, for compliance with the requirements set out in the applicable versions of the NRC *National Building Code of Canada* and the NRC *National Fire Code of Canada* ; have the review carried out by one or more independent external reviewers having specific expertise with such reviews; and, submit the results of the review in writing to CNSC staff.

The licensee shall design, build, modify, and otherwise carry out work related to the nuclear facility in compliance with CSA Group standard N393-13, *Fire Protection for Facilities That Process, Handle, or Store Nuclear Substances*, the NRC *National Building Code of Canada* (2015), and the NRC *National Fire Code of Canada* (2015) for any new designs, excluding the construction of the PWMF storage building 4 which shall be in compliance with the NRC *National Building Code of Canada* (2010), and the NRC *National Fire Code of Canada* (2010).

Guidance

Guidance Publications

Org	Doc #	Title
CNSC	G-276	Human Factors Engineering Program Plans
CNSC	G-278	Human Factors Verification and Validation Plans
CSA Group	N290.12	Human factors in design for nuclear power plants
CSA Group	N291	Requirements for safety-related structures for nuclear power plants

With regard to modifications, the design basis for the facility should be documented and maintained to reflect design changes to ensure adequate configuration management. The design basis should be maintained to reflect new information, operating experience, safety analyses, and the resolution of safety issues or the correction of deficiencies. The impacts of the design changes should be fully assessed, addressed, and accurately reflected in the safety analyses prior to implementation.

The design program should minimize the potential for human error and promote safe and reliable system performance through the consideration of human factors in the design of facilities, systems, and equipment.

Licence Condition 5.2 Pressure Boundary

The licensee shall implement and maintain a pressure boundary program and have in place a formal agreement with an Authorized Inspection Agency.

Preamble

This LC ensures that an Authorized Inspection Agency (AIA) will be subcontracted directly by the licensee. An AIA is an organization recognized by the CNSC as authorized to register designs and procedures, perform inspections, and other functions and activities as defined by CSA Group standard N285.0, *General Requirements for Pressure-Retaining Systems and Components in CANDU Nuclear Power Plants* and its applicable referenced publications (e.g., CSA Group standard B51, *Boiler, Pressure Vessel, and Pressure Piping Code* and the National Board Inspection Code). The AIA is accredited by the American Society of Mechanical Engineers (ASME) as stipulated by NCA-5121 of the ASME Boiler & Pressure Vessel Code.

Compliance Verification Criteria

Licensee Documents that Require Notification of Change

Doc #	Title	Prior Notice
N-LIST-00531-10003	Index to OPG Pressure Boundary Program Elements	N
N-MAN-01913.11-10000	Pressure Boundary Program Manual	N
N-CORR-00531-20012	Authorized Inspection Agency Service Agreement[1]	Y
N-PROC-MP-0082	Design Registration	Y
N-PROG-MP-0004	Pressure Boundary	Y
N-PROC-MP-0040	System and Item Classification	Y

Note: [1]Termination of the agreement is considered a change that requires prior written notification to the CNSC.

Licensing Basis Publications

Org	Doc #	Title	Version	Effective Date
ASME	B31.1	Power Piping	2010	Implemented
CSA Group	B51	Boiler, pressure vessel, and pressure piping code	2009 and Update No. 1	Implemented
CSA Group	N285.0	General requirements for pressure-retaining systems and components in CANDU nuclear power plants	2008 and Updates No. 1 and 2; and Annex N of N285.0-12 and Update No. 1	Implemented

Org	Doc #	Title	Version	Effective Date
NFPA	NFPA-24	Standard for the Installation of Private Fire Service Mains and Their Appurtenances	2010	Implemented
NFPA	NFPA-20	Standard for the Installation of Stationary Pumps for Fire Protection	2010 and Amendment 1 and Amendment 2	Implemented

For the purpose of the following, "registered", "accepted", and "approved" means either by the Commission or by a person authorized by the Commission, or by an AIA.

For the PWMF, OPG shall:

- Comply with CSA Group standard N285.0-08, *General Requirements for Pressure-Retaining Systems and Components in CANDU Nuclear Power Plants.*
- Design, manufacture, fabricate, install, modify, repair, test, examine, inspect, or otherwise perform work related to vessels, boilers, systems, piping, fittings, parts, components, and supports in accordance with the technical requirements in CSA Group standard N285.0-08, *General Requirements for Pressure-Retaining Systems and Components in CANDU Nuclear Power Plants*. Where indicated by this standard, OPG shall have the following:
  - registered designs for piping systems, components, fittings, and supports;
  - accepted overpressure protection reports;
  - approved code classifications, including applicable construction standards;
  - registered welding and brazing procedures;
  - accepted mechanical joint procedures;
  - qualified welders, welding operators, brazers, and examination personnel;
  - accepted quality assurance and quality control programs;
  - accepted plans and procedures; and,
  - markings for vessels, boilers, piping systems, fittings, parts, components, and supports.
- Operate vessels, boilers, piping systems, fittings, components, and supports safely and keep them in a safe condition. OPG shall:
  - follow accepted work plans and procedures to test, maintain, or alter overpressure protection devices;
  - comply with operating limits specified in certificates, orders, designs, overpressure protection reports, and applicable codes and standards; and,
  - have any certified boiler or vessel that is in operation or use inspected and certified by an authorized inspector according to an accepted schedule.

- Keep records of regulatory approvals and other documents required under this section and the standards applicable to the work or equipment.
- Personnel conducting non-destructive examinations shall be certified in accordance with the edition of CAN/CGSB 48.9712/ISO 9712 currently adopted for use by the National Certification Body of Natural Resources Canada for the appropriate examination method. If the National Certification Body does not offer certification for a specific inspection method, the relevant alternate requirements of Clause 11.3 of CSA Group standard N285.0-08, *General Requirements for Pressure-Retaining Systems and Components in CANDU Nuclear Power Plants* shall apply to ensure that personnel are appropriately trained and qualified.
- Have a formal agreement with an AIA to perform activities as defined in CSA Group standard N285.0-08, *General Requirements for Pressure-Retaining Systems and Components in CANDU Nuclear Power Plants*. OPG shall provide the Commission with a copy of the agreement.
- Maintain a pressure boundary program document roadmap in compliance with Annex N of CSA Group standard N285.0-12 (2012 and Update No. 1), *General Requirements for Pressure-Retaining Systems and Components in CANDU Nuclear Power Plants*.

Classification, Registration, and Reconciliation Procedures

OPG procedures describing the classification, registration, and reconciliation processes and the associated controls to ensure compliance with CSA Group standard N285.0-08, *General Requirements for Pressure-Retaining Systems and Components in CANDU Nuclear Power Plants* shall form a part of the pressure boundary program.

OPG shall provide prior written notification to the Commission, or to a person authorized by the Commission, of any changes to the procedures describing the classification, registration, and reconciliation process.

Overpressure Protection Report

OPG shall provide written notification to the Commission, or a person authorized by the Commission, of new or revised overpressure protection reports after the final registration. The notification may be provided in the form of a letter.

Quality Assurance and Quality Control Programs

OPG's pressure boundary quality assurance program shall comply with Clause 10 of CSA Group standard N285.0-08, *General Requirements for Pressure-Retaining Systems and Components in CANDU Nuclear Power Plants* except for Subclause 10.2.6. Repair and replacement activities are to comply with Subclause 10.3 of CSA Group standard N285.0-08, *General Requirements for Pressure-Retaining Systems and Components in CANDU Nuclear Power Plants*.

Class 6 or exempt-from-classification components that are required to be registered shall be subject to the quality requirements of CSA Group standard B51-09 (2009 and Update No. 1), *Boiler, Pressure Vessel, and Pressure Piping Code*. OPG's pressure boundary quality control programs for these components shall be reviewed and approved by the AIA.

Classification and Registration of Fire Protection Systems

Fire protection systems, and associated fittings and components are to be classified as Code Class 6, designed to ASME B31.1 (2010), *Power Piping*, and registered.

The following fittings and components may be exempt from requiring Canadian Registration Numbers provided they meet the following exemption criteria:

- fittings and components that are cUL or ULC listed and are suitable for the expected environmental conditions and maximum pressures; or
- pressurized cylinders and tubes such as extinguishers, inert gas and foam tanks, which bear Transport Canada approvals, and are suitable for the expected environmental conditions and maximum pressures; or
- buried fire protection piping when in compliance with NFPA-24 (2010), *Standard for the Installation of Private Fire Service Mains and Their Appurtenances*.

Testing of buried fire protection piping systems designed to the ASME piping codes may be exempt from ASME pressure testing requirements if the pressure testing is performed to NFPA-24 (2010), *Standard for the Installation of Private Fire Service Mains and Their Appurtenances*.

Authorized Inspection Agency

OPG shall arrange for the AIA inspectors to have access to all areas of the OPG facilities and records, and to the facilities and records of OPG's pressure boundary contractors and material organizations as necessary for the purposes of performing inspections and other activities required by CSA Group standard N285.0-08, *General Requirements for Pressure-Retaining Systems and Components in CANDU Nuclear Power Plants*.

A copy of the signed Agreement shall be provided to the CNSC. During the licence period, the licensee shall notify CNSC in writing of any change to the terms and conditions of the Agreement, including termination of the Agreement.

OPG shall provide the inspectors of the AIA with: information, reasonable advance notice, and time necessary to plan and perform inspections and other activities required by the standards.

Where a variance or deviation from the standard exists, the licensee must first submit the proposed resolution to the AIA for evaluation, and then to the CNSC for consent. The licensee must demonstrate that meeting the code requirement is impracticable and the proposed resolution shall not be implemented without the prior written consent of CNSC staff. A variance or deviation related to Code Edition, Code Classification, and Legacy Registration issues may be submitted directly to the CNSC without prior AIA evaluation.

Design registration services for pressure boundaries shall be provided by an AIA legally entitled under the *Provincial Boilers and Pressure Vessels Acts* and Regulations to register designs. Registration of piping systems shall be done by the Technical Standards and Safety Authority who are legally entitled to register designs in Ontario.

Delegation of Authority

The statement "or a person authorized by the Commission" reflects to whom the Commission has delegated certain authority. The delegation of authority by the Commission to act as a "person authorized by the Commission" is applied to the incumbents of the following positions:

- Director, Wastes and Decommissioning Division;
- Director General, Directorate of Nuclear Cycle and Facilities Regulations; and,
- Executive Vice-President and Chief Regulatory Operations Officer, Regulatory Operations Branch.

Guidance

Guidance Publications

Org	Doc #	Title
OPG	N-REF-01913.11-10001	Temporary Leak Maintenance by Leak Mitigation Process

SCA – FITNESS FOR SERVICE

Licence Condition 6.1 Fitness for Service Program

The licensee shall implement and maintain a fitness for service program.

Preamble

The SCA Fitness for Service covers activities that impact the physical condition of SSCs to ensure that they remain effective over time. Fitness for service includes programs that ensure equipment is available to perform its intended design function when called upon to do so.

This is accomplished by establishing an integrated set of programs and activities that ensure that safety performance requirements for critical SSCs are met on an ongoing basis. Aging management includes practices which address physical aging of SSCs as well as obsolescence issues as technology changes.

Compliance Verification Criteria

Licensee Documents that Require Notification of Change

Doc #	Title	Prior Notice
N-STD-MP-0028	Conduct of Engineering	N
N-PROG-MP-0009	Design Management	N
N-PROG-MA-0026	Equipment Reliability	N
N-PROG-MP-0008	Integrated Aging Management	N
W-PROG-WM-0001	Nuclear Waste Management	Y
00104-PLAN-79171-00002	Ontario Power Generation Dry Storage Container – Base (Underside) Inspection Plan	Y
00104-PLAN-79171-00001	Used Fuel Dry Storage Container Aging Management Plan	Y

Licensing Basis Publications

Org	Doc #	Title	Version	Effective Date
CNSC	REGDOC-2.6.3	Aging Management	2014	Implemented

For nuclear-related SSCs identified in accordance with OPG document N-STD-MP-0028, *Conduct of Engineering*, OPG shall establish inspection, testing and maintenance programs required to ensure continued safe operation of the facility.

Every year, the licensee shall include and submit to CNSC staff the inspection results and their evaluations, resulting from the in-service inspections and aging management of Dry Storage Containers (DSCs) in accordance with OPG document 00104-PLAN-79171-00001, *Used Fuel Dry Storage Container Aging Management Plan* and OPG document 00104-PLAN-79171-00002, *Ontario Power Generation Dry Storage Container – Base (Underside) Inspection Plan*, as part of the annual report.

Guidance

Guidance Publications

Org	Doc #	Title
IAEA	SSG-15	Storage of Spent Nuclear Fuel
CSA Group	N291	Requirements for safety-related structures for nuclear power plants
CNSC	REGDOC-2.6.2	Maintenance Programs for Nuclear Power Plants

The licensee should develop and implement life cycle management plans for nuclear safety-related pressure boundary systems and components and an aging management plan for safety-related structures.

The life cycle management plans for nuclear safety-related pressure boundary systems and components, and the aging management plan for safety-related structures should apply a systematic and integrated approach to establish, implement, and improve programs to manage aging and obsolescence of SSCs. The life cycle management plans should include structured, forward-looking inspection and maintenance schedules, requirements to monitor and trend aging effects and any preventative actions necessary to minimize and control aging degradation of the SSCs.

SCA – RADIATION PROTECTION

Licence Condition 7.1 Radiation Protection

> The licensee shall implement and maintain a radiation protection program, which includes a set of action levels. When the licensee becomes aware that an action level has been reached, the licensee shall notify the Commission within seven days.

Preamble

The *Radiation Protection Regulations* require that the licensee implement a radiation protection program and also ascertain and record doses for each person who perform any duties in connection with any activity that is authorized by the NSCA or is present at a place where that activity is carried on. This program must ensure that doses to persons (including workers) do not exceed prescribed dose limits and are kept As Low As Reasonably Achievable (the ALARA principle), social and economic factors being taken into account.

The regulatory dose limit to workers and the general public are explicitly provided in the *Radiation Protection Regulations*.

Action levels (ALs) are designed to alert licensees before regulatory dose limits are reached. By definition, if an AL referred to in a licence is reached, a loss of control of some part of the associated radiation protection program may have occurred, and specific action is required, as defined in the *Radiation Protection Regulations* and the licence. ALs are not intended to be static and are to reflect operating conditions in the facility.

Specific regulatory requirements related to the implementation of all aspects of a radiation protection program, including ALs are found in the *Radiation Protection Regulations*, *Class I Nuclear Facilities Regulations*, *General Nuclear Safety and Control Regulations*, and *Nuclear Substances and Radiation Devices Regulations*.

Compliance Verification Criteria

Licensee Documents that Require Notification of Change

Doc #	Title	Prior Notice
N-REP-03420-10011	Occupational Radiation Protection Action Levels for Nuclear Waste Management Facilities	Y
N-PROG-RA-0013	Radiation Protection	Y

A written report shall be submitted by the licensee to the Commission within 21 days of the licensee becoming aware that an AL has been reached.

The current ALs for the PWMF are given in the table below. In the event of a discrepancy between the table below and the licensee documentation upon which they are based, the licensee documentation shall be considered the authoritative source.

Application	Action Level	Observations
DOSE TO WORKERS Individual worker external whole body radiation dose received on a job greater than planned.	0.5 mSv (50 mrem)	The AL is exceeded if a person receives an external whole body dose that equals or exceeds 0.5 mSv above the Electronic Personal Dosimeter dose alarm set point in a shift.
WORKER EXPOSURE Individual worker receives a single intake of tritium oxide in which the unplanned component is estimated over a predetermined activity.	600 kBq/L (16 µCi/L)	The AL is exceeded if a person receives a single intake of tritium oxide (tritiated water) in which the unplanned component of the initial concentration immediately after intake is estimated to equal or exceed 600 kBq/L (16 µCi/L) (representing a nominal unplanned exposure of 0.5 mSv [50 mrem]).
WORKER EXPOSURE Individual worker receives an intake of a radionuclide other than tritium attributable to a single event that equals or exceeds a predetermined activity.	0.025 of an Annual Limit of Intake	The AL is exceeded if a person receives an intake of a radionuclide other than tritium (in the form of tritium oxide) attributable to a single event that equals or exceeds 0.025 of an Annual Limit of Intake as defined in International Commission on Radiation Protection (ICRP) 68 *Dose Coefficients for Intakes of Radionuclides by Workers* (representing a nominal unplanned exposure of 0.5 mSv [50 mrem]).
CONTAMINATION CONTROL Total surface contamination levels greater than a predetermined activity in Zone 1.	3.7×10^4 Bq/m^2 (1 µCi/m^2) (beta-gamma) 3.7×10^3 Bq/m^2 (0.1 µCi/m^2) (alpha)	The AL is exceeded if the total (fixed and loose) surface contamination levels greater than 3.7×10^4 Bq/m^2 (1 µCi/m^2) (beta-gamma) or 3.7×10^3 Bq/m^2 (0.1 µCi/m^2) (alpha) are found in Zone 1.

The licensee shall review and, if necessary, revise the ALs specified above at least once every five years in order to validate their effectiveness. The results of such reviews shall be provided to CNSC staff for review and acceptance. CNSC staff expect the ALs to be next reviewed, and revised if necessary, in 2022.

Guidance

Guidance Publications

Org	Doc #	Title
CNSC	G-129	Keeping Radiation Exposures and Doses "As Low As Reasonably Achievable (ALARA)"
CNSC	G-228	Developing and Using Action Levels

SCA – CONVENTIONAL HEALTH AND SAFETY

Licence Condition 8.1 Conventional Health and Safety

The licensee shall implement and maintain a conventional health and safety program.

Preamble

As of April 1, 1998, nuclear facilities owned and operated by Ontario Hydro were exempted from application of Part I, Part II, and Part III of the *Canada Labour Code*. This was established as per the following Consolidated Regulations: *SOR/98-179*, *SOR/98-180*, and *SOR/98-181*. The PWMF is now regulated by the *Occupational Health and Safety Act of Ontario* and the *Labour Relations Act*. Should any inconsistencies arise between the provincial and federal legislations, the federal laws would prevail to the extent of the inconsistency.

Compliance Verification Criteria

Licensee Documents that Require Notification of Change

Doc #	Title	Prior Notice
OPG-POL-0001	Employee Health and Safety Policy	N
OPG-PROG-0010	Health and Safety Management System Program	N

The licensee has the prime responsibility for safety at all times. This responsibility cannot be delegated or contracted to another organization or entity. The licensee shall ensure that contractors and other organizations present on site are informed of, and uphold their roles and responsibilities related to conventional health and safety.

Guidance

None provided.

SCA – ENVIRONMENTAL PROTECTION

Licence Condition 9.1 Environmental Protection

The licensee shall implement and maintain an environmental protection program, which includes a set of action levels. When the licensee becomes aware that an action level has been reached, the licensee shall notify the Commission within seven days.

Preamble

Licensees set Environmental Action Levels (EAL) and related parameters, so as to provide early warnings of any actual or potential losses of control of the environmental protection program. EALs are precautionary levels and are set far below the actual Derived Release Limits (DRL). EALs are designed to alert licensees before DRLs are reached. They are specific doses of radiation or other parameters that, if reached, may indicate a loss of control of the licensee's environmental protection program.

The release of hazardous substances is regulated by the CNSC as well as both the Ontario Ministry of the Environment, Conservation and Parks (MECP) and Environment and Climate Change Canada (ECCC) through various acts and regulations.

- The environmental protection SCA includes the following SpAs:
- Effluent and emissions control (releases);
- Environmental management system (EMS);
- Assessment and monitoring;
- Protection of the public; and
- Environmental Risk Assessment.

Compliance Verification Criteria

Licensee Documents that Require Notification of Change

Doc #	Title	Prior Notice
OPG-PROG-0005	Environmental Management System	N
OPG-POL-0021	Environmental Policy	N
N-PROC-OP-0025	Management of Environmental Monitoring Program	Y
N-STD-OP-0031	Monitoring of Nuclear and Hazardous Substances in Effluent	Y
P-REP-07701-00001	Environmental Risk Assessment Report for Pickering Nuclear	Y

Doc #	Title	Prior Notice
P-REP-03482-00006	Derived Release Limits and Environmental Action Levels for Pickering Nuclear	Y

Licensing Basis Publications

Org	Doc #	Title	Version	Effective Date
CNSC	REGDOC-2.9.1, Section 4.6	Environmental Protection: Environmental Principles, Assessments and Protection Measures	2016	Implemented
CSA Group	N288.1	Guidelines for calculating derived release limits for radioactive material in airborne and liquid effluents for normal operation of nuclear facilities	2014	Implemented
CSA Group	N288.3.4	Performance testing of nuclear air-cleaning systems at nuclear facilities	2013	Implemented
CSA Group	N288.4	Environmental monitoring program at class I nuclear facilities and uranium mines and mills	2015	Implemented
CSA Group	N288.5	Effluent monitoring programs at class I nuclear facilities and uranium mines and mills	2011	Implemented
CSA Group	N288.6	Environmental risk assessments at class I nuclear facilities and uranium mines and mills	2012	Implemented
CSA Group	N288.7	Groundwater protection programs at Class I nuclear facilities and uranium mines and mills	2015	December 31, 2020

Effluent and Emissions Control (Releases)

The licensee shall ensure effluent monitoring for nuclear and hazardous substances is designed, implemented and managed to respect applicable laws and to incorporate best practices. The effluent monitoring program shall provide for control of airborne and waterborne effluents. Effluent monitoring is a risk-informed activity, which assures quantifying of the important releases of the nuclear and hazardous substances into the environment.

OPG PWMF Effluent Monitoring Program shall be compliant with CSA N288.5-2011 *Effluent Monitoring Programs at Class I Nuclear Facilities and Uranium Mines and Mills*.

Nuclear substances – Derived Release Limits (DRL)

The licensee shall control radiological releases to ALARA, within the DRLs, and take action to investigate cause(s) and correct the cause(s) of increased releases.

If any of the individual DRLs are exceeded, or if the sum of individual releases (expressed as a fraction of the relevant DRL) exceeds unity, it indicates that the licensee is in non-compliance with the public dose limit of 1 mSv/year as per the *Radiation Protection Regulations*.

The DRLs are considered part of the licensing basis. Changes to these limits are subject to LC G.1. The DRLs for this facility are summarized in the table below. In the event of a discrepancy between the table below and the licensee documentation upon which they are based, the licensee documentation shall be considered the authoritative source (assuming that the licensee has followed its own change control process.

Release Category	Radionuclide	DRL (Bq/year)
Air	Tritium (HTO)	1.02E+17
	Iodine (mixed fission products)	2.82E+15
	Carbon-14	2.69E+15
	Noble Gases[1]	2.66E+16
	Particulate – Gross Beta-Gamma	4.25E+11
	Particulate – Gross Alpha	7.49E+10
Water	Tritium	7.87E+17
	Carbon-14	3.75E+13
	Gross Alpha	1.87E+12
	Gross Beta-Gamma	2.36E+10

[1]Noble gases DRL is in units of Bq-MeV

Note: The PWMF uses the DRLs established for the Pickering Site

These DRLs for radionuclides and radionuclide groups account for the most significant releases and are the focus of monitoring and reporting requirements.

Nuclear Substances – Environmental Action Levels (EAL)

OPG must develop and implement EALs. The EALs are considered part of the licensing basis. Changes to these limits are subject to LC G.1. The EALs for this facility are summarized in the table below. In the event of a discrepancy between the table below and the licensee documentation upon which they are based, the licensee documentation shall be considered the authoritative source (assuming that the licensee has followed its own change control process).

Further to the requirements of LC 3.2, OPG shall notify the Commission within seven days of becoming aware that an action level has been reached.

The current EALs for PWMF are given in the following table:

Release Category	Radionuclide	EALs: Gaseous Releases (Bq/week)
Air	Tritium (HTO)	2.03E+14
	Iodine	5.65E+09
	Carbon-14	5.38E+12
	Noble Gases[1]	5.32E+13
	Particulate – Gross Beta-Gamma	8.57E+08
Release Category	**Radionuclide**	**EALs: Liquid Releases (Bq/month)**
Water	Tritium (HTO)	6.29E+15
	Carbon-14	3.00E+11
	Gross Beta-Gamma	1.49E+10

[1]Noble gases EAL is in units of Bq-MeV.

Note: EAL for gross alpha is not specified since it is not a routinely monitored radionuclide group at the PNGS or PWMF because its activity is below the threshold value specified in the standard for radioactivity monitoring in effluents.

Note: The PWMF uses the EALs established for the Pickering Site.

Hazardous Substances

The licensee shall control hazardous substance releases according to the limits defined in accordance with the applicable environmental compliance approvals, provincial and other federal legislation and take action to investigate and correct the cause(s) of increased releases.

Environmental Management System (EMS)

The objective of the environmental protection policies, programs and procedures is to establish adequate provisions for protection of the environment. This shall be accomplished through an integrated set of documented activities of an environmental management system (EMS).

OPG shall implement and maintain an environmental management program to assess environmental risks associated with its nuclear activities, and to ensure these activities are conducted in such a way that adverse environmental effects are prevented or mitigated. OPG environmental management program shall be compliant with REGDOC-2.9.1, *Environmental Protection Policies, Programs and Procedures*, version 2016 section 4.6.

OPG shall ensure that all aspects of its environmental management program are effectively implemented in order to assure compliance with environmental regulatory requirements and expectations, including those set in the International Organization for Standardization 14001, *Environmental Management Systems*. OPG's EMS is registered to the ISO-14001. Having the ISO-14001certification is not part of the CNSC requirement; however it shows that a third party recognized OPG Environmental Management System as being in accordance with the standard.

Assessment and Monitoring

An environmental monitoring program consists of a risk-informed set of integrated and documented activities to sample, measure, analyze, interpret, and report the following:

- the concentration of hazardous and/or nuclear substances in environmental media to assess one or both of
  - exposure of receptors to those substances; and
  - the potential effects on human health, safety, and the environment;
- the intensity of physical stressors and/or their potential effect on human health and the environment; and
- the physical, chemical, and biological parameters of the environment normally considered in design of the EMP.

OPG Pickering's Environmental Monitoring Program is a site wide monitoring program (PNGS & PWMF) shall be compliant with CSA N288.4-2010 *Environmental Monitoring Programs at Class I Nuclear Facilities and Uranium Mines and Mills*.

Groundwater monitoring

The licensee shall implement the requirements of CSA Group standard N288.7-15, *Groundwater Protection Programs at Class I Nuclear Facilities and Uranium Mines and Mills* by December 31, 2020.

Protection of the public

This aspect relates to the assessment of predicted human health effects measured and potential quantities of hazardous substance in the environment (abiotic and biotic) of the Darlington NPPs. This aspect is linked to the Dose to the public SPA as well as the Environmental Risk Assessment SPA and addressed mainly under LC G.1 (Licensing Basis).

Environmental Risk Assessment

In accordance with CSA N288.4 and N288.5, the ERA establishes the basis for both the environmental monitoring program and the effluent monitoring program. The ERA shall be updated periodically with the results from the environmental and effluent monitoring programs in order to confirm the effectiveness of any additional mitigation measures needed.

OPG Pickering's ERA is a site wide ERA encompassing PNGS and PWMF and shall be compliant with CSA N288.6- 2012 *Environmental Risk Assessments at Class I Nuclear Facilities and Uranium Mines and Mills.*

Guidance

Guidance Publications

Org	Doc #	Title
CNSC	G-228	Developing and Using Action Levels
CNSC	REGDOC 2.9.1	Environmental Protection: Environmental Principles, Assessments and Protection Measures, Version 1.1
CSA	N288.2	Guidelines for Calculating the Radiological Consequences to the Public of a Release of Airborne Radioactive Material for Nuclear Reactor Accidents
CSA	N288.8	Establishing and implementing action levels for releases to the environment from nuclear facilities

It is recommended that the licensee provide to the CNSC a copy of the reports sent to the MECP and ECCC on hazardous releases.

Licence Condition 9.2 Environmental Assessment Follow-up Program

The licensee shall implement an environmental assessment follow-up program.

Preamble

In 2002, OPG identified its intent to expand the capacity of the PWMF by constructing and operating two additional storage buildings (#3 and #4) at the PWMF Phase II site. Between 2002 and 2004, a screening level Environmental Assessment (EA) under the CEAA 1992 was carried out for the proposed PWMF Phase II project.

In May 2004, the Commission issued a *Record of Proceedings, including Reasons for Decision for the PWMF Phase II EA* concluding that the project, taking into account the implementation of mitigation measures, is not likely to cause significant adverse environmental effects.

The EA process identified the need for an EA follow-up program for the PWMF Phase II project.

Compliance Verification Criteria

Licensee Documents that Require Notification of Change

Doc #	Title	Prior Notice
92896-REP-07701.8-00001	Pickering Waste Management Facility Phase II – Environmental Assessment Follow-up Plan	N

This LC requires that the ongoing environmental assessment follow-up program be completed and that progress on completion be reported annually.

Guidance

None provided.

SCA – EMERGENCY MANAGEMENT AND FIRE PROTECTION

Licence Condition 10.1 Emergency Preparedness Program

The licensee shall implement and maintain an emergency preparedness program.

Preamble

Emergency management covers emergency plans and emergency preparedness programs which exist for emergencies and for non-routine conditions. It also includes any results of exercise participation.

Compliance Verification Criteria

Licensee Documents that Require Notification of Change

Doc #	Title	Prior Notice
N-STD-RA-0036	Radioactive Materials Transportation Emergency Response Plan	N
N-PROG-RA-0001	Consolidated Nuclear Emergency Plan	Y

Licensing Basis Publications

Org	Doc #	Title	Version	Effective Date
CNSC	REGDOC-2.10.1	Nuclear Emergency Preparedness and Response, Version 2	2017	Implemented

OPG's nuclear emergency preparedness program is documented in the *Consolidated Nuclear Emergency Plan* (CNEP). The CNEP governs the Pickering site, where the PWMF is located. The CNEP deals with emergency situations that endanger the safety of onsite staff, the environment, and the public. The PNGS Emergency Response Team is the primary responder for the PWMF Phase I. For Phase II, emergency, medical, and fire response is provided by the City of Pickering, with the PNGS Emergency Response Team as the secondary responder. A Memorandum of Understanding, dated January 1, 2014 exists for the provision of emergency, medical, and fire response between the City of Pickering and OPG for PWMF Phase II.

Guidance

None provided.

Licence Condition 10.2 Fire Protection Program

The licensee shall implement and maintain a fire protection program.

Preamble

Licensees require a comprehensive fire protection program to ensure the licensed activities do not result in unreasonable risk to the health and safety of persons and to the environment due to fire and to ensure that the licensee is able to efficiently and effectively respond to emergency fire situations.

Fire protection provisions, including response, are required for the design, construction, commissioning, operation, maintenance, and decommissioning of nuclear facilities. Fire provisions cover structures, systems, and components that support the plant operation and extend within the exclusion area. External events, such as an aircraft crash or threats, are addressed by LC 12.1.

Compliance Verification Criteria

Licensee Documents that Require Notification of Change

Doc #	Title	Prior Notice
N-PROG-RA-0012	Fire Protection	Y

Licensing Basis Publications

Org	Doc #	Title	Version	Effective Date
CSA Group	N393-13	Fire protection for facilities that process, handle, or store nuclear substances	2013	Implemented
NRC	N/A	National Building Code of Canada (2015)	2015	TBD
NRC	N/A	National Fire Code of Canada (2015)	2015	TBD

To demonstrate compliance with the applicable codes and standards, the licensee shall: arrange for third party reviews of compliance with the requirements of the applicable versions of the NRC *National Building Code of Canada* and the NRC *National Fire Code of Canada* as per the intervals outlined in CSA Group standard N393-13, *Fire Protection for Facilities That Process, Handle, or Store Nuclear Substances*; have the review carried out by one or more independent external reviewers having specific expertise with such reviews; and, submit the results of the review in writing to CNSC staff.

New buildings within the PWMF Phase II licensed area shall comply with the requirements of CSA Group standard N393-13, *Fire Protection for Facilities That Process, Handle, or Store Nuclear Substances*, the NRC *National Building Code of Canada (2015)*, and the NRC *National Fire Code of Canada (2015)*.

Guidance

None provided.

SCA – WASTE MANAGEMENT

Licence Condition 11.1 Waste Management Program

The licensee shall implement and maintain a waste management program.

Preamble

The "waste management" safety and control area covers internal waste-related programs that form part of the facility's operations up to the point where the waste is removed from the facility to a separate waste management facility. This area also covers the planning for decommissioning.

CNSC Regulatory Document REGDOC-2.11, *Framework for Radioactive Waste Management and Decommissioning in Canada* defines radioactive waste as any material (liquid, gaseous or solid) that contains a radioactive "nuclear substance," as defined in section 2 of the NSCA, and which the owner has declared to be waste. In addition to containing nuclear substances, radioactive waste may also contain non-radioactive "hazardous substances," as defined in section 1 of the *General Nuclear Safety and Control Regulations*.

Compliance Verification Criteria

Licensee Documents that Require Notification of Change

Doc #	Title	Prior Notice
N-PROC-RA-0017	Segregation and Handling of Radioactive Waste	N
OPG-STD-0156	Management of Waste and Other Environmentally Regulated Materials	N
W-PROG-WM-0001	Nuclear Waste Management	Y
N-PROG-RA-0013	Radiation Protection	Y

Licensing Basis Publications

Org	Doc #	Title	Version	Effective Date
CSA Group	N292.0	General principles for the management of radioactive waste and irradiated fuel	2014	Implemented
CSA Group	N292.2	Interim dry storage of irradiated fuel	2013	Implemented
CSA Group	N292.3	Management of low- and intermediate-level radioactive waste	2014	Implemented
CSA Group	N292.0	General principles for the management of radioactive waste and irradiated fuel	2019	December 21, 2021

OPG shall characterize its waste streams and minimize the production of all wastes taking into consideration the health and safety of workers and the environment, integrate waste management programs as a key element of the facility's safety culture, and regularly audit its program to maximize its efficiency.

With respect to the storage and management of spent nuclear fuel, the waste management program should reflect the fundamental safety concerns related to criticality, exposure, heat control, containment, and retrievability. That is, the systems that are designed and operated should assure subcriticality, control of radiation exposure, assure heat removal, assure containment, and allow retrievability.

Transition

The licensee shall implement the requirements of CSA Group standard N 292.0-19, *General Principles for the Management of Radioactive Waste and Irradiated Fuel* by December 21, 2021.

Guidance

Guidance Publications

Org	Doc #	Title
CNSC	REGDOC-2.11	Framework for Radioactive Waste Management and Decommissioning in Canada

The CNSC expects that OPG will implement and audit a facility and waste stream-specific waste management program to control and minimize the volume of radioactive waste generated by the licensed activity. Inclusion of a waste management program is a key component of the licensee's safety culture.

Licence Condition 11.2 Decommissioning Plan

The licensee shall maintain a decommissioning plan.

Preamble

Paragraph 3(k) of the *Class I Nuclear Facilities Regulations* requires that a licence application contain the proposed plan for the decommissioning of the nuclear facility.

This LC requires that the licensee maintain, at this point in the life-cycle, a Preliminary Decommissioning Plan (PDP).

A PDP provides an overview of the proposed decommissioning approach that is sufficiently detailed to assure that the proposed approach is, in light of existing knowledge, technically and financially feasible, and appropriate in the interests of health, safety, security and the protection of the environment. The PDP defines areas to be decommissioned and the general structure and sequence of the principle work packages. The PDP forms the basis for establishing and maintaining a financial arrangement (financial guarantee – see LC G.3) that will assure adequate funding of the decommissioning plan.

Compliance Verification Criteria

Licensee Documents that Require Notification of Change

Doc #	Title	Prior Notice
W-PROG-WM-0003	Decommissioning Program	Y
92896-PLAN-00960-00001	Preliminary Decommissioning Plan Pickering Waste Management Facility	Y

Licensing Basis Publications

Org	Doc #	Title	Version	Effective Date
CSA Group	N294-09	Decommissioning of facilities containing nuclear substances	2009	Implemented
CSA Group	N294-19	Decommissioning of facilities containing nuclear substances	2019	See Transition

The PDP is to be kept current to reflect any changes in the site or nuclear facility. The PDP is to be revised at a minimum every five years or when required by the Commission.

The PDP was last revised and submitted to the CNSC in 2017. OPG's next scheduled submission of the PDP for the PWMF is due to the CNSC in 2022.

Transition

The licensee shall implement the requirements of CSA Group standard N 294-19, *Decommissioning of Facilities Containing Nuclear Substances* for the next scheduled PDP revision due to the CNSC in 2022.

Guidance

Guidance Publications

Org	Doc #	Title
CNSC	G-219	Decommissioning Planning for Licensed Activities
CNSC	G-206	Financial Guarantees for the Decommissioning of Licensed Activities

SCA – SECURITY

Licence Condition 12.1 Security Program

The licensee shall implement and maintain a security program.

Preamble

Nuclear security puts in place provisions to prevent, detect and stop malevolent acts, such as theft, sabotage, unauthorized access, illegal transfer or other acts involving nuclear material, other radioactive substances or their associated facilities.

Compliance Verification Criteria

Licensee Documents that Require Notification of Change

Doc #	Title	Prior Notice
92896-REP-08160-00001	Pickering Waste Management Facility Phase II Security Report	N
92896-REP-08160-00001 ADD 001	Pickering Waste Management Facility Security Report Addendum	N
N-PROG-RA-0011	Nuclear Security	Y
N-PROC-RA-0135	Cyber Security	Y
W-LIST-08161-00001	Nuclear Waste Management Cyber Essential Assets	Y

Licensing Basis Publications

Org	Doc #	Title	Version	Effective Date
CNSC	RD-363	Nuclear Security Officer Medical, Physical, and Psychological Fitness	2008	Implemented
CNSC	REGDOC-2.2.4	Fitness for Duty, Volume III: Nuclear Security Officer Medical, Physical, and Psychological Fitness	2018	December 31, 2020
CNSC	REGDOC-2.12.1	High-Security Facilities, Volume II: Criteria for Nuclear Security Systems and Devices	2018	Implemented
CNSC	REGDOC-2.12.2	Site Access Security Clearance	2013	Implemented

The licensee shall ensure the identified vital areas within the nuclear facility are protected against design basis threats and any other credible threat identified in their threat and risk assessment documentation. The prime functions that must be maintained at the PWMF to prevent unacceptable radiological consequences are those of control, and contain.

The licensee shall maintain the operation, design, and analysis provisions credited in the above assessments as required to ensure adequate engineered safety barriers for the protection against malevolent acts. The provisions for the protection against malevolent acts shall be documented as part of a managed sub program or process within the management system. The licensee shall summarize changes in design, analysis, or operation procedures that are credited for the protection against malevolent acts in the annual threat and risk assessment, and submit a copy to the Commission upon request.

The licensee shall implement measures for the purpose of preventing and detecting unauthorized entry into a protected area or inner area at a high-security site, including:

- vehicle barriers and vehicle access control points;
- perimeter intrusion detection systems and devices;
- closed-circuit video systems/devices for applications in a protected area or inner area;
- security monitoring rooms; and,
- security monitoring room systems and devices.

The licensee shall develop, implement, and maintain a cyber-security program to protect against cyber-attacks on cyber essential assets for nuclear safety, nuclear security, emergency preparedness, and safeguards functions. The cyber security program includes the following elements:

- roles and responsibilities;
- policies and procedures;
- staff training and awareness;
- overall approach to cyber-security;
- change control and configuration management;
- incident response and recovery;
- periodic self-assessments;
- security controls; and
- identification and classification of cyber essential assets.

The licensee shall file an update of the security report with the CNSC a minimum of six months before the operating licence expires. If the site security program changes at any time, it must be brought to the attention of the Director of the Nuclear Security Division at the CNSC. The changes will then be assessed to determine if the report requires an immediate update or if the update can wait until the relicensing review.

Guidance

Guidance Publications

Org	Doc #	Title
CNSC	REGDOC-2.12.3	Security of Nuclear Substances: Sealed Sources and Category I, II, and III Nuclear Material, Version 2
CSA	N290.7	Cyber Security for Nuclear Power Plants and Small Reactor Facilities
IAEA	Nuclear Security Series No. 17 Technical Guidance	Computer Security at Nuclear Facilities
IAEA	Nuclear Security Series No. 4 Technical Guidance	Engineering Safety Aspects of the Protection of Nuclear Power Plants Against Sabotage
IAEA	Nuclear Security Series No. 13 Recommendations	Nuclear Security Recommendations on Physical Protection of Nuclear Material and Nuclear Facilities

Licence Condition 12.2 Construction

The licensee shall not carry out the activities referred to in paragraph (iii) of Part IV of this licence that relate to completed construction activities in paragraph (iv) of Part IV of this licence until the submission of the proposed security arrangements and measures for the new building, or any potential modifications to the protected area that may be associated with this new building, that is acceptable to the Commission or a person authorized by the Commission.

Preamble

None provided.

Compliance Verification Criteria

The operating licence authorizes the construction and operation of additional buildings at the PWMF. This LC requires that OPG submit the proposed security arrangements and measures for the new buildings, or any potential modifications to the protected area that may be associated with the new buildings prior to receiving CNSC authorization to operate these buildings.

The Commission, or a person authorized by the Commission, will confirm that acceptable security arrangements have been submitted prior to authorizing OPG to begin operations at the new buildings.

Delegation of Authority

The statement “or a person authorized by the Commission” reflects to whom the Commission has delegated certain authority. The delegation of authority by the Commission to act as a “person authorized by the Commission” is applied to the incumbents of the following positions:

- Director, Wastes and Decommissioning Division;
- Director General, Directorate of Nuclear Cycle and Facilities Regulations; and,
- Executive Vice-President and Chief Regulatory Operations Officer, Regulatory Operations Branch.

Guidance

None provided.

SCA – SAFEGUARDS AND NON-PROLIFERATION

Licence Condition 13.1 Safeguards Program

The licensee shall implement and maintain a safeguards program.

Preamble

Canada has entered into a Safeguards Agreement and an Additional Protocol (hereafter referred to as “safeguards agreements”) with the IAEA pursuant to its obligations under the *Treaty on the Non-Proliferation of Nuclear Weapons (INFCIRC/140)*. The objective of the Canada-IAEA safeguards agreements is for the IAEA to provide assurance on an annual basis to Canada and to the international community that all declared nuclear materials are in peaceful, non-explosive uses and that there is no indication of undeclared nuclear materials or activities. This conclusion confirms that Canada is in compliance with its obligations under the following Canada-IAEA safeguards agreements:

- *Agreement Between the Government of Canada and the International Atomic Energy Agency for the Application of Safeguards in Connection with the Treaty on the Non-Proliferation of Nuclear Weapons*; and,
- *Protocol Additional to the Agreement between Canada and the International Atomic Energy Agency for the Application of Safeguards in Connection with the Treaty on the Non-Proliferation of Nuclear Weapons*.

These are reproduced in *INFCIRC/164* and *INFCIRC/164/Add. 1*.

The scope of the non-proliferation program carried out under this licence is limited to tracking and reporting of foreign obligations and origins of nuclear material. Additionally, the import and export of controlled nuclear substances, equipment, and information identified in the *Nuclear Non-proliferation Import and Export Control Regulations* require separate authorization from the CNSC, consistent with section 3(2) of the *General Nuclear Safety and Control Regulations*.

Compliance Verification Criteria

Licensee Documents that Require Notification of Change

Doc #	Title	Prior Notice
N-PROG-RA-0015	Nuclear Safeguards	Y
N-STD-RA-0024	Nuclear Safeguards Implementation	Y

Licensing Basis Publications

Org	Doc #	Title	Version	Effective Date
CNSC	REGDOC-2.13.1	Safeguards and Nuclear Material Accountancy	2018	implemented
CNSC	REGDOC-2.13.1	Safeguards and Nuclear Material Accountancy	2018	October 29, 2021*

*For all aspects of the REGDOC-2.13.1 requirements related to non-fuel nuclear material inventory

The licensee shall not make changes to operation, equipment, or procedures that would affect the implementation of safeguards measures, except with the prior written approval of the Commission or a person authorized by the Commission.

With respect to the implementation of safeguards measures, changes made by the licensee to operation, equipment, or procedures as the result of agreements between the licensee, the CNSC, and the IAEA are considered routine.

If a requested change would adversely impact Canada's compliance with its safeguards agreements, CNSC staff do not have the authority to give approval, as this would violate the obligations arising from the Canada-IAEA safeguards agreement.

To avoid a potential non-compliance with REGDOC-2.13.1, section 8.1.1, when the Nuclear Material Accountancy Reporting (NMAR) e-business system is not available, OPG is to contact the CNSC International Safeguards Division (cnsc.sg.official.ccsn@canada.ca) to inform them of the issue and to seek guidance on how to fulfill reporting requirements. When OPG inventory change documents and physical-key measurement point inventory summaries are submitted using an alternative method, OPG will still be required to re-submit using the NMAR e-business system once the NMAR system becomes available. For additional information see CNSC letter e-doc 6039874.

Delegation of Authority

The statement "or a person authorized by the Commission" reflects to whom the Commission has delegated certain authority. The delegation of authority by the Commission to act as a "person authorized by the Commission" is applied to the incumbents of the following positions:

- Director, International Safeguards Division;
- Director General, Directorate of Security and Safeguards; and,
- Vice-President, Technical Support Branch.

Transition

The licensee shall implement the requirements of REGDOC-2.13.1, *Safeguards and Nuclear Material Accountancy* for non-fuel nuclear material inventory, by October 29, 2021.

Guidance

None provided.

SCA – PACKAGING AND TRANSPORT

Licence Condition 14.1 Packaging and Transport Program

The licensee shall implement and maintain a packaging and transport program.

Preamble

Transport of nuclear substances is subject to the *Transport of Dangerous Goods Regulations* (TDGR) and the *Packaging and the Transport of Nuclear Substances Regulations (2015)* (PTNSR).

Compliance Verification Criteria

Licensee Documents that Require Notification of Change

Doc #	Title	Prior Notice
W-PROG-WM-0002	Radioactive Material Transportation	N
N-STD-RA-0036	Radioactive Materials Transportation Emergency Response Plan	N
N-PROG-RA-0013	Radiation Protection	Y

The licensee shall implement and maintain a packaging and transport program that will ensure compliance with the requirements of the TDGR and the PTNSR, 2015.

Guidance

None provided.

FACILITY SPECIFIC

Licence Condition 15.1 Construction Plans

The licensee shall submit an environmental management plan, a construction verification plan and the project design requirements prior to the commencement of construction activities described in paragraph (iv) of Part IV of this licence.

Preamble

None provided.

Compliance Verification Criteria

Licensing Basis Publications

Org	Doc #	Title	Version	Effective Date
CSA Group	N393-13	Fire protection for facilities that process, handle, or store nuclear substances	2013	Implemented
NRC	N/A	National Building Code of Canada (2015)	2015	TBD
NRC	N/A	National Fire Code of Canada (2015)	2015	TBD

The CNSC will confirm that both an environmental management plan and a construction verification plan are in effect prior to the commencement of construction activities as authorized in paragraph (iv) of Part IV of this licence.

The CNSC will confirm that appropriate design requirements have been developed and submitted to the CNSC prior to the onset of construction activities. These design requirements for new buildings, with the exception of storage building 4, shall comply with the NRC *National Building Code of Canada (2015),* NRC *National Fire Code of Canada (2015)*, and CSA Group standard N393-13, *Fire Protection for Facilities That Process, Handle, or Store Nuclear Substances*.

Guidance

None provided.

Licence Condition 15.2 Commissioning Report

> The licensee shall not carry out the activities referred to in paragraph (iii) of Part IV of this licence that relate to completed construction activities in paragraph (iv) of Part IV of this licence until the submission of a commissioning report that is acceptable to the Commission or a person authorized by the Commission.

Preamble

None provided.

Compliance Verification Criteria

The Commission, or a person authorized by the Commission, will confirm that an acceptable commissioning report has been submitted prior to authorizing OPG to begin operations at any new buildings. Upon review and acceptance of the commissioning report, the Commission or a person authorized by the Commission, will provide formal notification that OPG is authorized to begin operations at the new building.

Delegation of Authority

The statement "or a person authorized by the Commission" reflects to whom the Commission has delegated certain authority. The delegation of authority by the Commission to act as a "person authorized by the Commission" is applied to the incumbents of the following positions:

- Director, Wastes and Decommissioning Division;
- Director General, Directorate of Nuclear Cycle and Facilities Regulations; and,
- Executive Vice-President and Chief Regulatory Operations Officer, Regulatory Operations Branch.

Guidance

None provided.

APPENDIX A: CHANGE CONTROL PROCESS

A change control process has been developed for revisions to the LCH to ensure that preparation and use of it is controlled and that all references are identified and maintained. A request to change this document can be initiated by either CNSC staff or the licensee. The change will be assessed by CNSC staff as follows:

1. The change request will be documented using the change request form;
2. The review will be coordinated by the project officer and appropriate specialists will be consulted for concurrence;
3. Approval will be obtained from the Director WDD, the DG DNCFR, or the EVP Ops, as appropriate;
4. The licensee will be consulted on the proposed changes;
5. If a dispute related to the proposed changes exists between the licensee and CNSC staff, the following process will be followed:
   5.1. A meeting will be scheduled between the parties;
   5.2. The decision and its rationale will be discussed and documented; and,
   5.3. If either party is not satisfied with the decision, the next stage of the process will be initiated as follows:
      5.3.1. A decision will be made by the Director WDD. If the decision is not satisfactory, it will be submitted to the DG DNCFR for resolution; or,
      5.3.2. A decision will be made by the DG DNCFR. If the decision is not satisfactory, it will be submitted to the EVP Ops for resolution; or,
      5.3.3. A decision will be made by the EVP Ops. If the decision is not satisfactory, it will be submitted to the Commission for resolution during a Commission Meeting. A final decision will be made by the Commission.
6. The LCH will be revised and approved by the Director WDD, the DG DNCFR, or the EVP Ops, as appropriate;
7. All changes to the LCH and any supporting information will be archived in the CNSC Records Office;
8. The document revision history will be revised in the Revision History section of the LCH; and,
9. A copy of the amended version of the LCH will be provided to the licensee and made available to CNSC staff.

Change Request Form

1. GENERAL INFORMATION			
File Plan #		**e-Doc #(s) for Change Request Form**	
Licensee	**Licence Number**	**LCH #, Rev/Version**	**Request Date**
Licensing Officer			

2. CHANGE(S) TO THE LCH			
#	**Description and Purpose**	**Proposed Change**	**References**
1	<initiator, nature, reason for change, e.g., administrative, change to a licensee doc, etc.>	<identify modifications, such as by track changes, highlighting, etc.>	<LC, page, section #, etc.>
2			

3. ASSESSMENT (text and/or e-Doc #s)			
#	**Division/Org**	**Comment**	**Disposition**
1	<division>		
	<division>		
	<licensee>		
	<division>		
2	etc.		

4. CONSENT TO MODIFY			
#	**Agreed**	**Comment**	
1			
2			
Name	**Title**	**Signature**	**Date**

5. LCH DOCUMENTATION AND DISTRIBUTION			
New LCH Number	**LCH Effective Date**	**e-Doc #** (include version number)	
CNSC Outgoing Notification		**e-Doc #**	**Date Sent**

APPENDIX B: DEFINITIONS AND ACRONYMS

DEFINITIONS

Accept	Accept means to indicate compliance with requirements.
Acceptable	Acceptable means to meet the requirements of CNSC staff.
Action Level	A specific dose of radiation or other parameter that, if reached, may indicate a loss of control of part of a licensee's radiation protection program and triggers a requirement for specific action to be taken (*Radiation Protection Regulations*; Glossary of CNSC Terminology).
Approval	Approval means the granting of consent by a regulatory body. Typically used to represent any form of consent from the regulatory body that does not meet the definition of authorization (IAEA Glossary).
Authorization	Authorization means the granting by a regulatory body or other governmental body of written permission for an operator to perform specified activities (IAEA Glossary): • Authorization could include, for example, licensing, certification, or registration. • The term authorization is also sometimes used to describe the document granting such permission. • Authorization is normally a more formal process than approval.
Boundary Conditions	The values of variables in a mathematical model that are assumed at the spatial bounds of the model (Glossary of CNSC Terminology).
Defence in Depth	A hierarchical deployment of different levels of diverse equipment and procedures to prevent the escalation of anticipated operational occurrences and to maintain the effectiveness of physical barriers placed between a radiation source or radioactive material and workers, members of the public or the environment, in operational states and, for some barriers, in accident conditions (Glossary of CNSC Terminology).
Design Basis	The range of conditions and events taken explicitly into account in the design of a nuclear facility, according to established criteria, such that the facility can withstand this range without exceeding authorized limits. Note: Design extension conditions are not part of the design basis (Glossary of CNSC Terminology).

Graduated Use of Force
The application of approved response force options following the RCMP incident management/intervention model or approved equivalent provincial police model (Glossary of CNSC Terminology).

Hazardous Substance
A substance, other than a nuclear substance, that is used or produced in the course of carrying on a licensed activity and that may pose a risk to the environment or the health and safety of persons (*Class II Nuclear Facilities and Prescribed Equipment Regulations*; *Uranium Mines and Mills Regulations*, Glossary of CNSC Terminology).

Licensing Basis
A set of requirements and documents for a regulated facility or activity comprising:

- the regulatory requirements set out in the applicable laws and regulations;
- the conditions and safety and control measures described in the facility's or activity's licence and the documents directly referenced in that licence; and,
- the safety and control measures described in the licence application and the documents needed to support that licence application.

(Glossary of CNSC Terminology).

Management System
The framework of processes, procedures and practices used to ensure that an organization can fulfill all tasks required to achieve its objectives safely and consistently. Note: The management system integrates all elements of an organization into one coherent system to enable all of the organization's objectives to be achieved. These elements include the structure, resources and processes. Personnel, equipment and organizational culture, as well as the documented policies and processes, are parts of the management system (Glossary of CNSC Terminology).

Notice of Non-Compliance
A notice of non-compliance (NNC) is issued when a non-compliance with the compliance CVC is confirmed through objective evidence obtained from reliable sources and based on verifiable facts. A NNC requires the licensee to take the necessary action(s) to correct the identified non-compliance and respond with one of the following:

- confirmation that compliance has been restored
- a timeframe for restoring compliance
- a timeframe within which a corrective action plan will be submitted

Notification	The submission of information by the licensee to CNSC staff.
Order	One of the regulatory tools the CNSC uses to compel someone to do something in the interests of health, safety, the environment, national security or compliance with Canada's international obligations. Failure to comply with an order can lead to further regulatory measures, including prosecution or licensing actions (Glossary of CNSC Terminology).
Person Authorized by the Commission	Person authorized by the Commission means the Director WDD, the DG DNCFR, or EVP Ops of the CNSC, unless otherwise specified.
Qualified Staff	Trained licensee staff, deemed competent and qualified to carry out tasks associated to their respective positions.
Recommendation	A written suggestion for improvement relating to good industry practice or the promotion of good performance.
Safe Direction	Safe direction means changes in facility safety levels which would not potentially result in: • a reduction in any safety margin; • a breakdown of barriers; • an increase (in certain parameters) above accepted limits; • an increase in risk; • impairments of special safety systems; • an increase in the risk of radioactive releases or spills of hazardous substances; • injuries to workers or members of the public; • introduction of a new hazard; or, • a reduction of the facility's defence in depth provisions.
Shall	For the purpose of this handbook, "shall" is used to express a requirement, i.e., a provision that the user is obliged to satisfy in order to comply with a CSA Group standard.
Worker	A person who performs work that is referred to in a licence (Glossary of CNSC Terminology).

ACRONYMS

The following is the list of acronyms used in this document:

μCi	Microcurie
AIA	Authorized Inspection Agency
AL	Action Level
ALARA	As Low As Reasonably Achievable
ASME	American Society of Mechanical Engineers
Bq	Becquerel
CANDU	CANada Deuterium Uranium
CNEP	Consolidated Nuclear Emergency Plan
CNSC	Canadian Nuclear Safety Commission
CSA	Canadian Standards Association
cUL	Underwriters Laboratories Inc. (‘c’ meets Canadian requirements)
CVC	Compliance Verification Criteria
DG	Director General
DNCFR	Directorate of Nuclear Cycle and Facilities Regulation
DRL	Derived Release Limit
DSC	Dry Storage Container
EA	Environmental Assessment
EAL	Environmental Action Level
ECCC	Environment and Climate Change Canada
EVP Ops	Executive Vice-President and Chief Regulatory Operations Officer
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiation Protection
INFCIRC	INFormation CIRCular
LC	Licence Condition
LCH	Licence Conditions Handbook
MECP	Ministry of the Environment, Conservation and Parks
mSv	Millisievert

NFPA	National Fire Protection Association
NNC	Notice of Non-Compliance
NRC	National Research Council Canada
NSCA	*Nuclear Safety and Control Act*
ONFA	Ontario Nuclear Funds Agreement
OPG	Ontario Power Generation Inc.
PDP	Preliminary Decommissioning Plan
PIDP	Public Information and Disclosure Program
PNGS	Pickering Nuclear Generating Station
PWMF	Pickering Waste Management Facility
SCA	Safety and Control Area
SSC	Systems, Structures, and Components
WDD	Wastes and Decommissioning Division
WFOL	Waste Facility Operating Licence

APPENDIX C: LIST OF LICENSING BASIS PUBLICATIONS

Doc #	Title	Version	LC
American Society of Mechanical Engineers Documents			
B31.1	Power Piping	2010	5.2
Canadian Nuclear Safety Commission Documents			
RD-363	Nuclear Security Officer Medical, Physical, and Psychological Fitness	2008	12.1
RD/GD-99.3	Public Information and Disclosure	2012	G.4 3.2
REGDOC-2.1.2	Safety Culture	2018	2.1
REGDOC-2.2.2	Personnel Training	2014	2.2
REGDOC-2.2.4	Fitness for Duty: Managing Worker Fatigue	2017	2.1
REGDOC-2.2.4	Fitness for Duty, Volume II: Managing Alcohol and Drug Use, version 2	2017	2.1
REGDOC-2.2.4	Fitness for Duty, Volume III: Nuclear Security Officer Medical, Physical, and Psychological Fitness	2018	12.1
REGDOC-2.6.3	Aging Management	2014	6.1
REGDOC-2.9.1	Environmental Protection: Environmental Principles, Assessments and Protection Measures	Section 4.6, 2016	9.1
REGDOC-2.10.1	Nuclear Emergency Preparedness and Response, Version 2	2017	10.1
REGDOC-2.12.2	Site Access Security Clearance	2013	12.1

Doc #	Title	Version	LC
REGDOC-2.12.3	Security of Nuclear Substances – Sealed Sources	2013	12.1
REGDOC-2.13.1	Safeguards and Nuclear Material Accountancy	2018	13.1
REGDOC 3.1.2	Reporting Requirements, Volume 1: Non-Power Reactor Class I Nuclear Facilities and Uranium Mines and Mills	2018	3.2
REGDOC 3.2.1	Public Information and Disclosure	2018	G.4 3.2
Canadian Standards Association Group Documents			
B51	Boiler, pressure vessel, and pressure piping code	2009 and Update No. 1	5.2
N285.0	General requirements for pressure-retaining systems and components in CANDU nuclear power plants	2008 and Updates No. 1 and 2; and Annex N of N285.0-12 and Update No. 1	5.2
N286	Management system requirements for nuclear facilities	2012	1.1
N286.7	Quality assurance of analytical, scientific, and design computer programs	2016	4.1
N288.1	Guidelines for calculating derived release limits for radioactive material in airborne and liquid effluents for normal operation of nuclear facilities	2014	9.1
N288.3.4	Performance testing of nuclear air-cleaning systems at nuclear facilities	2013	9.1
N288.4	Environmental monitoring program at class I nuclear facilities and uranium mines and mills	2015	9.1
N288.5	Effluent monitoring programs at class I nuclear facilities and uranium mines and mills	2011	9.1

Doc #	Title	Version	LC
N288.6	Environmental risk assessments at class I nuclear facilities and uranium mines and mills	2012	9.1
N288.7	Groundwater protection programs at Class I nuclear facilities and uranium mines and mills	2015	9.1
N292.0	General principles for the management of radioactive waste and irradiated fuel	2014	4.1 11.1
N292.2	Interim dry storage of irradiated fuel	2013	4.1 11.1
N292.3	Management of low- and intermediate-level radioactive waste	2014	4.1 11.1
N294	Decommissioning of facilities containing nuclear substances	2009	G.3 11.2
N393	Fire protection for facilities that process, handle, or store nuclear substances	2013	5.1 10.2 15.1
National Fire Protection Association			
NFPA-20	Standard for the Installation of Stationary Pumps for Fire Protection	2010 and Amendment 1 and Amendment 2	5.2
NFPA-24	Standard for the Installation of Private Fire Service Mains and Their Appurtenances	2010	5.2
National Research Council Canada Documents			
N/A	National Building Code of Canada	2015	5.1 10.2 15.1
N/A	National Fire Code of Canada	2015	5.1 10.2 15.1

APPENDIX D: LIST OF LICENSEE DOCUMENTS THAT REQUIRE NOTIFICATION OF CHANGE

Doc #	Title	Prior Notice	LC
N/A	CNSC Financial Security and ONFA Access Agreement between OPG, the Province of Ontario and the CNSC effective January 1, 2018	Y Requires CNSC acceptance of change	G.3
00104-PLAN-79171-00001	Used Fuel Dry Storage Container Aging Management Plan	Y	6.1
00104-PLAN-79171-00002	Ontario Power Generation Dry Storage Container – Base (Underside) Inspection Plan	Y	6.1
92896-CORR-00531-01031	Application for Renewal of Pickering Waste Management Facility Operating Licence	N	G.1 3.1
92896-CORR-00531-01075	Additional Information to Support the Application for Renewal of Pickering Waste Management Facility Operating Licence	N	G.1 3.1
92896-CORR-00531-01478	Change Request Application for Amendment to the Pickering Waste Management Facility (PWMF) Waste Facility Operating Licence WFOL W4-350.00/2028	N	G.1
92896-CORR-00531-01530 P	OPG - Addendum to the Application for Amendment to the Pickering Waste Management Facility, Waste Facility Operating Licence WFOL-W4-350.00/2028	N	G.1
92896-OPP-01911.1-00001	Operating Policies and Principles, Pickering Waste Management Facility	Y	3.1 3.2
92896-PLAN-00960-00001	Preliminary Decommissioning Plan Pickering Waste Management Facility	Y	11.2
92896-REP-07701.8-00001	Pickering Waste Management Facility Phase II – Environmental Assessment Follow-up Plan	N	9.2
92896-REP-08160-00001	Pickering Waste Management Facility Phase II Security Report	N	12.1
92896-REP-08160-00001 ADD 001	Pickering Waste Management Facility Security Report Addendum	N	12.1

Doc #	Title	Prior Notice	LC
92896-SR-01320-10002	Pickering Waste Management Facility – Safety Report	Y	3.1 4.1
N-CHAR-AS-0002	Nuclear Management System	Y	1.1
N-CORR-00531-06752 N-CORR-00531-19076	Authorized Inspection Agency Service Agreement	Y	5.2
N-LIST-00531-10003	Index to OPG Pressure Boundary Program Elements	N	5.2
N-MAN-01913.11-10000	Pressure Boundary Program Manual	N	5.2
N-POL-0001	Nuclear Safety Policy	N	1.1
N-PROC-AS-0077	Nuclear Safety Culture Assessment	N	1.1
N-PROC-MP-0040	System and Item Classification	Y	5.2
N-PROC-MP-0082	Design Registration	Y	5.2
N-PROC-OP-0025	Management of Environmental Monitoring Program	Y	9.1
N-PROC-OP-0043	Waste Management	N	11.1
N-PROC-OP-0047	Hours Of Work Limits And Managing Worker Fatigue	Y	2.1
N-PROC-RA-0017	Segregation and Handling of Radioactive Waste	N	11.1
N-PROC-RA-0020	Preliminary Event Notification	N	3.2
N-PROC-RA-0135	Cyber Security	Y	12.1
N-PROC-TR-0008	Systematic Approach to Training	N	2.2
N-PROG-AS-0002	Human Performance	N	2.1
N-PROG-MA-0026	Equipment Reliability	N	6.1
N-PROG-MP-0001	Engineering Change Control	N	5.1
N-PROG-MP-0004	Pressure Boundary	Y	5.2
N-PROG-MP-0008	Integrated Aging Management	N	6.1

Doc #	Title	Prior Notice	LC
N-PROG-MP-0009	Design Management	N	5.1 6.1
N-PROG-MP-0014	Reactor Safety Program	N	4.1
N-PROG-RA-0001	Consolidated Nuclear Emergency Plan	Y	10.1
N-PROG-RA-0002	Conduct of Regulatory Affairs	N	3.2
N-PROG-RA-0003	Performance Improvement	N	3.2
N-PROG-RA-0011	Nuclear Security	Y	12.1
N-PROG-RA-0012	Fire Protection	Y	10.2
N-PROG-RA-0013	Radiation Protection	Y	7.1 11.1 14.1
N-PROG-RA-0015	Nuclear Safeguards	Y	13.1
N-PROG-TR-0005	Training	N	2.2
N-REP-03420-10011	Occupational Radiation Protection Action Levels for Nuclear Waste Management Facilities	Y	7.1
N-STD-AS-0013	Nuclear Public Information Disclosure	N	G.4
N-STD-AS-0020	Nuclear Management Systems Organizations	N	1.1
N-STD-AS-0023	Nuclear Safety Oversight	N	1.1
N-STD-MP-0027	Configuration Management	N	5.1
N-STD-MP-0028	Conduct of Engineering	N	5.1 6.1
N-STD-OP-0031	Monitoring of Nuclear and Hazardous Substances in Effluent	Y	9.1
N-STD-RA-0024	Nuclear Safeguards Implementation	Y	13.1
N-STD-RA-0036	Radioactive Materials Transportation Emergency Response Plan	N	10.1 14.1

Doc #	Title	Prior Notice	LC
P-REP-03482-00006	Derived Release Limits and Environmental Action Levels for Pickering Nuclear	Y	9.1
P-REP-07701-00001	Environmental Risk Assessment Report for Pickering Nuclear	Y	9.1
OPG-POL-0001	Employee Health and Safety Policy	N	8.1
OPG-POL-0021	Environmental Policy	N	9.1
OPG-PROC-0019	Records and Document Management	N	G.2
OPG-PROG-0001	Information Management	N	G.2
OPG-PROG-0005	Environmental Management System	N	9.1
OPG-PROG-0009	Items and Services Management	N	1.1
OPG-PROG-0010	Health and Safety Management System Program	N	1.1 8.1
W-LIST-08161-00001	Nuclear Waste Management Cyber Essential Assets	Y	12.1
W-PROG-WM-0001	Nuclear Waste Management	Y	1.1 3.1 6.1 10.1 11.1
W-PROG-WM-0002	Radioactive Material Transportation	N	14.1
W-PROG-WM-0003	Decommissioning Program	Y	11.2

APPENDIX E: LIST OF GUIDANCE PUBLICATIONS

Doc #	Title	Version	LC
Canadian Nuclear Safety Commission Documents			
G-129	Keeping Radiation Exposures and Doses 'As Low As Reasonably Achievable'	2004	7.1
G-206	Financial Guarantees for the Decommissioning of Licensed Activities	2000	G.3 11.2
G-219	Decommissioning Planning for Licensed Activities	2000	G.3 11.2
G-228	Developing and Using Action Levels	2001	7.1 9.1
G-276	Human Factors Engineering Program Plans	2003	2.1 5.1
G-278	Human Factors Verification and Validation Plans	2003	2.1 5.1
REGDOC-2.1.1	Management Systems	2019	1.1
REGDOC-2.2.1	Human Factors	2019	2.1
REGDOC-2.2.2	Personnel Training (Section 5)	2016	2.2
REGDOC-2.2.5	Minimum Staff Complement	2019	2.1
REGDOC-2.6.2	Maintenance Programs for Nuclear Power Plants	2017	6.1
REGDOC-2.9.1	Environmental Protection: Environmental Principles, Assessments and Protection Measures, Version 1.1	2017	9.1
REGDOC-2.11	Framework for Radioactive Waste Management and Decommissioning in Canada	2018	11.1

Doc #	Title	Version	LC
REGDOC-2.12.3	Security of Nuclear Substances: Sealed Sources and Category I, II, and III Nuclear Material, Version 2	2019	12.1
Canadian Standards Association Group Documents			
N288.2	Guidelines for Calculating the Radiological Consequences to the Public of a Release of Airborne Radioactive Material for Nuclear Reactor Accidents	1991 (R2013)	9.1
N288.8	Establishing and implementing action levels for releases to the environment from nuclear facilities	2017	9.1
N290.7	Cyber Security for Nuclear Power Plants and Small Reactor Facilities	2014	12.1
N290.12	Human factors in design for nuclear power plants	2014	5.1
N291	Requirements for safety-related structures for nuclear power plants	2015	5.1 6.1
International Atomic Energy Agency Documents			
Nuclear Security Series No. 4 Technical Guidance	Engineering Safety Aspects of the Protection of Nuclear Power Plants Against Sabotage	2007	12.1
Nuclear Security Series No. 13 Recommendations	Nuclear Security Recommendations on Physical Protection of Nuclear Material and Nuclear Facilities	Revision 5	12.1
Nuclear Security Series No. 17 Technical Guidance	Computer Security at Nuclear Facilities	2011	12.1
SSG-15	Storage of Spent Nuclear Fuel	2012	6.1
Ontario Power Generation			
N-REF-01913.11-10001	Temporary Leak Maintenance by Leak Mitigation Process	2019	5.2

PDF Ref.: e-Doc 5188230
Word Ref.: e-Doc 5156473
File/Dossier: 2.05

WASTE FACILITY OPERATING LICENCE

PICKERING WASTE MANAGEMENT FACILITY

I) LICENCE NUMBER: **WFOL-W4-350.00/2028**

II) LICENSEE: Pursuant to section 24 of the *Nuclear Safety and Control Act* this licence is issued to:

Ontario Power Generation Inc.
700 University Avenue
Toronto, Ontario
M5G 1X6

III) LICENCE PERIOD: This licence is valid from **April 1, 2018** to **August 31, 2028** unless suspended, amended, revoked, replaced, or transferred.

IV) LICENSED ACTIVITIES:

This licence authorizes the licensee to:

(i) operate the Pickering Waste Management Facility ("the facility") located at the Pickering Nuclear Generating Station, City of Pickering, Regional Municipality of Durham, Province of Ontario;

(ii) possess, transfer, use, process, package, manage, and store nuclear substances that are required for, associated with or arise from the activities described in (i);

(iii) transport Category II nuclear materials that are associated with the activities described in (i) on the site of the Pickering Nuclear Generating Station;

(iv) carry out the site preparation, construction, or construction modifications at the facility associated with the authorized additional processing and storage buildings, when on completion will result in a total of no more than 1 dry storage container processing building and no more than 6 used fuel dry storage buildings; and,

(v) possess and use prescribed equipment and prescribed information that are required for, associated with or arise from the activities described in (i), (ii), (iii), and (iv).

V) EXPLANATORY NOTES:

(i) Unless otherwise provided for in this licence, words and expressions used in this licence have the same meaning as in the *Nuclear Safety and Control Act* and associated Regulations.

(ii) The Pickering Waste Management Facility licence conditions handbook (LCH) provides compliance verification criteria used to meet the conditions of this licence. The LCH also provides information on delegation of authority and document version control.

VI) CONDITIONS:

G GENERAL

G.1 Licensing Basis for Licensed Activities

The licensee shall conduct the activities described in Part IV of this licence in accordance with the licensing basis, defined as:

(i) the regulatory requirements set out in the applicable laws and regulations;

(ii) the conditions and safety and control measures described in the facility's or activity's licence and the documents directly referenced in that licence;

(iii) the safety and control measures described in the licence application and the documents needed to support that licence application;

unless otherwise approved in writing by the Canadian Nuclear Safety Commission (hereinafter "the Commission").

G.2 Notification of Changes

The licensee shall give written notification of changes to the facility or its operation, including deviation from design, operating conditions, policies, programs and methods referred to in the licensing basis.

G.3 Financial Guarantee

The licensee shall maintain a financial guarantee for decommissioning that is acceptable to the Commission.

G.4 Public Information and Disclosure

The licensee shall implement and maintain a public information and disclosure program.

1 MANAGEMENT SYSTEM

1.1 Management System

The licensee shall implement and maintain a management system.

1.2 Management of Contractors

The licensee shall ensure that every contractor working at the facility complies with this licence.

2 HUMAN PERFORMANCE MANAGEMENT

2.1 Human Performance Program

The licensee shall implement and maintain a human performance program.

2.2 Training Program

The licensee shall implement and maintain a training program.

3 OPERATING PERFORMANCE

3.1 Operations Program

The licensee shall implement and maintain an operating program, which includes a set of operating limits.

3.2 Reporting Requirements

The licensee shall implement and maintain a program for reporting to the Commission or a person authorized by the Commission.

4 SAFETY ANALYSIS

4.1 Safety Analysis Program

The licensee shall implement and maintain a safety analysis program.

5 PHYSICAL DESIGN

5.1 Design Program

The licensee shall implement and maintain a design program.

5.2 Pressure Boundary

The licensee shall implement and maintain a pressure boundary program and have in place a formal agreement with an Authorized Inspection Agency.

6 FITNESS FOR SERVICE

6.1 Fitness for Service Program

The licensee shall implement and maintain a fitness for service program.

7 RADIATION PROTECTION

7.1 Radiation Protection

The licensee shall implement and maintain a radiation protection program, which includes a set of action levels. When the licensee becomes aware that an action level has been reached, the licensee shall notify the Commission within seven days.

8 CONVENTIONAL HEALTH AND SAFETY

8.1 Conventional Health and Safety Program

The licensee shall implement and maintain a conventional health and safety program.

9 ENVIRONMENTAL PROTECTION

9.1 Environmental Protection

The licensee shall implement and maintain an environmental protection program, which includes a set of action levels. When the licensee becomes aware that an action level has been reached, the licensee shall notify the Commission within seven days.

9.2 Environmental Assessment Follow-up Program

The licensee shall implement an environment assessment follow-up program.

10 EMERGENCY MANAGEMENT AND FIRE PROTECTION

10.1 Emergency Preparedness Program

The licensee shall implement and maintain an emergency preparedness program.

10.2 Fire Protection Program

The licensee shall implement and maintain a fire protection program.

11 WASTE MANAGEMENT

11.1 Waste Management Program

The licensee shall implement and maintain a waste management program.

11.2 Decommissioning Plan

The licensee shall maintain a decommissioning plan.

12 SECURITY

12.1 Security Program

The licensee shall implement and maintain a security program.

12.2 Construction

The licensee shall not carry out the activities referred to in paragraph (ii) of Part IV of this licence that relate to completed construction activities in paragraph (iv) of Part IV of this licence until the submission of the proposed security arrangements and measures for the new building, or any potential modifications to the protected area that may be associated with this new building, that is acceptable to the Commission or a person authorized by the Commission.

13 SAFEGUARDS AND NON-PROLIFERATION

13.1 Safeguards Program

The licensee shall implement and maintain a safeguards program.

14 PACKAGING AND TRANSPORT

14.1 Packaging and Transport Program

The licensee shall implement and maintain a packaging and transport program.

15 FACILITY-SPECIFIC

15.1 Construction Plans

The licensee shall submit an environmental management plan, a construction verification plan and the project design requirements prior to the commencement of construction activities described in paragraph (iv) of Part IV of this licence.

15.2 Commissioning Report

The licensee shall not carry out the activities referred to in paragraph (ii) of Part IV of this licence that relate to completed construction activities in paragraph (iv) of Part IV of this licence until the submission of a commissioning report that is acceptable to the Commission or a person authorized by the Commission.

SIGNED at OTTAWA, this 6th day of February, 2018

M. Binder

Michael Binder, President
On behalf of the Canadian Nuclear Safety Commission

Canadian Nuclear Safety Commission
Commission canadienne de sûreté nucléaire

Record of Decision

In the Matter of

Applicant	Ontario Power Generation
Subject	Application to Renew the Waste Facility Operating Licence for the Pickering Waste Management Facility
Public Hearing Date	April 13, 2017

Canada

RECORD OF DECISION

Licensee:	Ontario Power Generation
Address/Location:	700 University Avenue, Toronto, Ontario, M5G 1X6
Purpose:	Application to Renew the Waste Facility Operating Licence for the Pickering Waste Management Facility
Application received:	October 28, 2016
Date of public hearing:	April 13, 2017
Location:	Canadian Nuclear Safety Commission (CNSC) Public Hearing Room, 280 Slater St., 14th. Floor, Ottawa, Ontario
Members present:	M. Binder, Chair; S. Demeter; S. McEwan; S. A. Soliman; R. Velshi
Secretary:	M.A. Leblanc
Recording Secretary:	B. Gerestein, S. Baskey and M. Hornof
Senior General Counsel:	L. Thiele

Licensee Represented By	Document Number
L. Morton, Vice President, Nuclear Waste Management R. Manley, Vice President, Nuclear Regulatory Affairs and Stakeholder Relations G. Sullivan, Director, Eastern Waste Operations and Deep Geologic Repository R. McCalla, Director, Environment Operations Support D. Witzke, Director, Nuclear Waste Engineering A. Webster, Director, Operations Business Support K. Powers, Director, Nuclear Public Affairs C. Lorencez, Director, Nuclear Safety	CMD 17-H5.1 CMD 17-H5.1A CMD 17-H5.1B CMD 17-H5.1C
CNSC staff	**Document Number**
H. Tadros, K. Glenn, S. Oue, M. Rinker, C. Cole, Y. Wang, R. Tennant, C. Purvis, K. Sauvé, K. Noble, M. Snow, C. Ducros, M. Beaudette, R. Garg and A. McAllister	CMD 17-H5 CMD 17-H5.A CMD 17-H5.B
Intervenors	**Document Number**
See appendix A	
Others	
Environment and Climate Change Canada represented by D. Kim	

Licence: Renewed

Table of Contents

1.0 INTRODUCTION

1. Ontario Power Generation (OPG) has applied to the Canadian Nuclear Safety Commission[1] (CNSC) for the renewal of the Waste Facility Operating Licence (WFOL) for the Pickering Waste Management Facility (PWMF). The current operating licence, WFOL-W4-350.02/2018, expires on March 31, 2018. OPG applied for a renewal of its licence for a period of 11 years, until August 31, 2028. In addition to the licence renewal request, OPG also requested authorization for the site preparation and construction of a new dry storage container (DSC) processing building and two new DSC storage buildings #5 and #6, as well as for the construction of DSC storage building #4 (carried over from the current licence).

2. The PWMF is located in the City of Pickering, Ontario, on the north shore of Lake Ontario at the site of the Pickering Nuclear Generating Station (NGS). The PWMF licence authorizes OPG to process and store DSCs containing used nuclear fuel from the Pickering NGS reactor operations and intermediate-level radioactive waste generated from the refurbishment (re-tubing) of the Pickering NGS Units 1 – 4 conducted between 1984 and 1992. OPG carries out all transfers of used fuel from the Pickering NGS reactors to the DSCs, and subsequently to the PWMF, entirely on the Pickering NGS site.

3. As part of its licence renewal application, OPG has requested permission to construct or modify an additional DSC Processing Building and additional DSC storage buildings that would allow OPG to store all of the used fuel generated at the Pickering NGS until the end of its commercial operational life. The proposed new DSC Processing Building would increase OPG's processing capabilities from 50 DSCs per year to approximately 100 DSCs per year. Following construction of the new DSC Processing Building, OPG plans to take the existing DSC Processing Building out of service and decommission it at a later date.

4. In November 2016, up to $50,000 in funding to participate in this licensing process was made available to Indigenous groups, not-for-profit organizations and members of the public through the CNSC's Participant Funding Program (PFP). A Funding Review Committee (FRC), independent of the CNSC, recommended that up to $42,251 in participant funding be provided to four applicants. These applicants were required, by virtue of being in receipt of the funding, to submit a written intervention and make an oral presentation during the public hearing commenting on OPG's application. One PFP recipient withdrew its PFP request prior to the public hearing.

[1] The Canadian Nuclear Safety Commission is referred to as the "CNSC" when referring to the organization and its staff in general, and as the "Commission" when referring to the tribunal component.

Issue

5. In considering the application, the Commission was required to decide:

a) what environmental assessment review process to apply in relation to this application;

b) whether OPG is qualified to carry on the activity that the licence would authorize; and

c) whether, in carrying on that activity, OPG would make adequate provision for the protection of the environment, the health and safety of persons and the maintenance of national security and measures required to implement international obligations to which Canada has agreed.

Public Hearing

6. Pursuant to section 22 of the NSCA, the President of the Commission established a Panel of the Commission to review the application. The President of the Commission authorized R. Velshi to participate in this hearing, as she became engaged with this matter while still holding office as a Member of the Commission. The Commission, in making its decision, considered information presented for a public hearing which began on April 13, 2017, in Ottawa, Ontario. The public hearing was conducted in accordance with the *Canadian Nuclear Safety Commission Rules of Procedure* (the Rules).[2] During the public hearing, the Commission considered written submissions and heard oral presentations from OPG (CMD 17-H5.1, CMD 17-H5.1A, CMD 17-H5.1B and CMD 17-H5.1C) and CNSC staff (CMD 17-H5, CMD 17-H5.A and CMD 17-H5.B). The Commission also considered oral and written submissions from 12 intervenors (see Appendix A for a list of interventions). The April 13, 2017 oral portion of the public hearing was webcast live via the CNSC website, and video archives were available for a minimum of a three-month period thereafter.

7. Following the public hearing held on April 13, 2017, the Commission concluded that further information was required in order to come to a decision. Based on requests from intervenors and on the information provided by OPG during the oral hearing regarding OPG's completion of the 2017 Pickering NGS Environmental Risk Assessments (ERA) – which included the operations of the PWMF – the Commission was of the view that information about the 2014 and 2017 Pickering NGS ERAs, as they related to the PWMF, were required for the Commission to render a decision in this matter. On this basis, the Commission directed that the 2014 and 2017 Pickering NGS ERAs related to the PWMF be provided to the Commission and the public, and entered into the record for consideration as part of this hearing.

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[2] Statutory Orders and Regulations (SOR)/2000-211.

8. On June 21, 2017, the Commission issued a *Notice of Continuation of Public Hearing* to allow for the required additional information to be submitted to the Commission and entered into the record for this hearing.[3] The Commission invited existing intervenors in this matter to provide the Commission with additional written submissions in respect of the 2014 and 2017 ERAs by July 21, 2017. The Commission also invited OPG and CNSC staff to submit supplementary written submissions in this matter by August 21, 2017. Upon request from CNSC, the Commission approved an extension for CNSC staff to file the supplementary submission in this matter no later than October 31, 2017. The Commission notes that OPG submitted a supplementary submission on August 18, 2017. In light of the deadline extension given to CNSC staff, OPG was also invited to submit any additional supplementary submissions by October 31, 2017 but declined to do so. The Commission decided that it would deliberate on this matter following its receipt and consideration of all supplementary written submissions.

9. On June 21, 2017, OPG submitted the 2014 and 2017 Pickering NGS ERAs as they related to the PWMF. The Commission received two supplemental submissions from intervenors (CMDs 17-H5.11B and 17-H5.13C), a supplemental submission from OPG on August 18, 2017 (CMD 17-H5.1C) and a supplemental submission on October 30, 2017 from CNSC staff (CMD 17-H5.B).

2.0 DECISION

10. Based on its consideration of the matter, as described in more detail in the following sections of this *Record of Decision*, the Commission concluded that OPG is qualified to carry on the activity that the licence will authorize. The Commission is of the opinion that OPG, in carrying on that activity, will make adequate provision for the protection of the environment, the health and safety of persons and the maintenance of national security and measures required to implement international obligations to which Canada has agreed. Therefore,

> the Commission, pursuant to section 24 of the *Nuclear Safety and Control Act*, renews the Waste Facility Operating Licence issued to Ontario Power Generation Inc. for its Pickering Waste Management Facility located in Pickering, Ontario. The renewed licence, WFOL-W4-350.00/2028, is valid from April 1, 2018 until August 31, 2028.

11. The Commission includes in the licence the conditions as recommended by CNSC staff in CMD 17-H5. The Commission also delegates authority to senior CNSC staff for the purposes of licence conditions 5.2, 12.2, 13.1 and 15.2 as recommended by CNSC staff.

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[3] *Notice of Continuation of Public Hearing*, Ontario Power Generation Inc. – Application to Renew the Waste Facility Operating Licence for the Pickering Waste Management Facility, June 21, 2017.

12. The Commission authorizes the construction activities as outlined in the proposed licence. The Commission expects OPG to carry out the appropriate safety assessments for any new buildings that OPG constructs at the PWMF site.

13. The Commission considers the environmental review that was conducted by CNSC staff to be acceptable and thorough.

14. With this decision, the Commission directs CNSC staff to report annually on the performance of OPG and the PWMF, as part of the annual *Regulatory Oversight Report for Canadian Nuclear Power Plants* (NPP ROR). CNSC staff shall present this report at a public proceeding of the Commission, where members of the public will be able to participate.

15. The Commission encourages OPG to make available to the public data on contaminants of primary concern and directs that CNSC staff report on the status of public disclosure by OPG as part of the NPP ROR.

16. The Commission notes that CNSC staff can bring any matter to the Commission as applicable. The Commission directs CNSC staff to inform the Commission on an annual basis of any changes made to the Licence Conditions Handbook (LCH).

17. The Commission notes that, following a hearing held in October 2017, the Commission accepted OPG's consolidated financial guarantee for its nuclear facilities in Ontario.[4] This includes the PWMF.

3.0 ISSUES AND COMMISSION FINDINGS

18. In making its licence renewal decision for the PWMF, the Commission considered a number of issues relating to OPG's qualification to carry out the proposed activities and the adequacy of the proposed measures for protecting the environment, the health and safety of persons, national security and international obligations to which Canada has agreed.

19. The Commission examined CNSC staff's assessment of OPG's performance in all 14 safety and control areas (SCAs) and in relation to several other matters of regulatory interest over the current licence period. Details and the Commission's consideration of information submitted by OPG in support of its licence renewal application, of CNSC staff assessments and of interventions submitted in relation to this matter are provided in the following sections of the *Record of Decision.*

[4] CNSC Record of Decision – Ontario Power Generation Inc., "Financial Guarantee for the Future Decommissioning of Ontario Power Generation Inc.'s Facilities in Ontario", issued on November 28, 2017.

3.1 Environmental Assessments

3.1.1 Application of the Canadian Environmental Assessment Act, 2012

20. In coming to its decision, the Commission was first required to determine whether an Environmental Assessment (EA) under the *Canadian Environmental Assessment Act, 2012*[5] (CEAA 2012), was required.

21. The Commission recognizes that the application submitted by OPG is for the PWMF licence renewal and notes that a licence renewal is not a designated project under CEAA 2012.

22. The Commission recognizes that OPG submitted, as part of its application, requests for the authorization for the site preparation and construction of a new dry storage container (DSC) processing building and two new DSC storage buildings #5 and #6, as well as for the construction of DSC storage building #4 (carried over from the current licence).

23. CNSC staff explained that as part of this licensing renewal process, an EA determination was carried out and OPG's PWMF licence renewal application was assessed against the requirements in the *Regulations Designating Physical Activities*[6] to determine whether an EA under CEAA 2012 should be carried out in respect of the proposed activities. CNSC staff submitted that a review of OPG's application determined that, since the PWMF licence renewal application was for an existing facility and that the PWMF did not process or use nuclear substances, CNSC staff found that an EA under CEAA 2012 was not required, as this proposal was not enumerated in the *Regulations Designating Physical Activities*.

24. The OPG representative informed the Commission that an EA specific to the construction of the proposed DSC Processing Building and the new storage buildings had not been undertaken, but that the proposed facilities were assessed under CEAA 1992 within the scope of the 2007 Pickering B Refurbishment and Continued Operation EA which found that, with mitigation measures, the environmental impacts of the construction and operation of new facilities as proposed would not be significant. The OPG representative also informed the Commission that the environmental effects from the construction and operation of the proposed facilities are well characterized and understood. CNSC staff confirmed the information provided by OPG.

25. Based on the information provided for this hearing, the Commission is satisfied that an EA under CEAA 2012 is not required in regard to this licence renewal nor prior to the approval of the proposed construction projects.

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[5] Statutes of Canada (S.C.) 2012, chapter (c.) 19, section (s.) 52.
[6] SOR/2012-147.

3.1.2 Environmental Assessment under the NSCA

26. The Commission also considered the completeness and adequacy of the EA that CNSC staff conducted under the NSCA for this licence renewal and for the construction of the proposed buildings. CNSC staff findings included, but were not limited to:

- OPG maintained adequate environmental protection programs that met CNSC regulatory requirements.
- OPG conducted the Pickering NGS 2014 environmental risk assessment (ERA) using appropriate methodology and sufficiently conservative data, and in accordance with N288.6-12, *Environmental risk assessment at Class I nuclear facilities and uranium mines and mills*,[7] with the ERA showing that human health and the environment remained protected.
- The results of the CNSC's 2014 and 2015 Independent Environmental Monitoring Program (IEMP) confirmed that the public and the environment near the Pickering site remained protected from the releases from the facility.

The Commission also notes that CNSC staff submitted that the 2017 ERA was carried out in accordance with the specifications of N288.6-12 and that the 2017 ERA showed that significant human health or ecological effects attributable to current operations at the PWMF were unlikely. CNSC staff reaffirmed to the Commission that OPG had and would continue to make adequate provision for the protection of the environment and the health of persons.

27. The Commission considered the intervention from Lake Ontario Waterkeeper which expressed the opinion that, since an EA under CEAA 2012 had not been conducted for the construction of the new facilities, the Commission did not have sufficient information to make a decision in this matter. Lake Ontario Waterkeeper further opined that OPG and CNSC staff were relying on outdated EAs in their assessments on this matter, including a 2003 Screening EA conducted under *Canadian Environmental Assessment Act*[8] (CEAA 1992), and expressed the view that, although the previously conducted EAs were for projects similar to the proposed PWMF construction and expansion activities, notable differences existed. In this regard, Lake Ontario Waterkeeper provided the Commission with information on site aspects that it felt should be included in an EA under CEAA 2012 for the proposed construction activities.

28. In its consideration of Lake Ontario Waterkeeper's intervention, the Commission requested further information regarding the differences between an EA carried out under CEAA 2012 and an EA carried out under the NSCA. In its intervention, Lake Ontario Waterkeeper submitted that the EA carried out under CEAA 1992 in 2003 was more comprehensive that an EA carried out under the NSCA and that an EA under CEAA 2012 provided for public participation. CNSC staff informed the Commission

[7] N288.6-12, *Environmental risk assessment at Class I nuclear facilities and uranium mines and mills,* CSA Group, 2012.
[8] S.C.1992, c.37.

that, in addition to the information in the EA Report, EA-related information regarding the impacts of the PWMF were considered in ERAs, inspection reports, through compliance verification activities and in environmental monitoring reports. CNSC staff also submitted that the CNSC's licensing process and RORs provided multiple opportunities for public participation during a facility's life-cycle.

29. Through their interventions, Northwatch and Lake Ontario Waterkeeper submitted for the Commission's consideration, examples of information that the intervenors felt should be considered in an EA prior to OPG being granted approval for the proposed construction and expansion projects. Lake Ontario Waterkeeper opined that potential impacts from liquid effluents, surface and storm water runoff and groundwater had not been adequately characterized and the Commission requested additional information in this regard. CNSC staff responded that these factors had been thoroughly assessed in previous EAs and considered in ERA and explained that liquid effluents generated at the PWMF site were routed to the Pickering NGS active liquid waste management system for processing, that groundwater discharge pathways were monitored by OPG and that storm water runoff from the PWMF was appropriately managed and did not drain into the eastern wetlands. The Commission is satisfied that the liquid effluent resulting from the PWMF operations has been sufficiently characterized and is adequately managed. Further, based on the information submitted for this hearing, the Commission is satisfied that storm water runoff at the PWMF does not have a significant impact on the surrounding environment.

30. In its intervention, Northwatch submitted the view that insufficient design information was available pertaining to site preparation for the proposed facilities and that this was a further indication that a comprehensive EA was required prior to approval of these projects. The OPG representative explained that the preliminary design for the proposed facility was not yet available because the detailed engineering had not yet been completed. OPG further submitted that the proposed buildings would be built and operated using similar design and technology as the existing buildings. The Commission is satisfied with the adequacy of the information submitted in this regard and notes that the site preparation and construction projects will be subject to continuous CNSC regulatory oversight.

31. The Commission is satisfied that the environmental assessment that was conducted by CNSC staff for the PWMF licence renewal and construction of proposed buildings was acceptable and thorough. The Commission notes that the NSCA provides a strong regulatory framework for environmental protection. Whether an EA under CEAA 2012 is required or not, the NSCA and its regulations provide for the protection of the environment and the health and safety of persons.

3.1.3 Conclusion on Environmental Assessments

32. The Commission considered the requirement of an EA under CEAA 2012 in relation to the proposed licence renewal and construction activities. Based on the information provided for this hearing, the Commission concludes that the licence renewal and construction projects are not designated projects under CEAA 2012 and that an EA under CEAA 2012 is not required prior to their approval. Further, the Commission is satisfied that OPG has made, and will continue to make, adequate provision for the protection of the environment throughout the proposed renewed licence period.

33. Following its consideration of the information provided on the record for this hearing, the Commission concludes that an EA conducted under the NSCA and its regulations was appropriate for the PWMF licence renewal application.

3.2 Management System

34. The Commission examined OPG's Management System which covers the framework that establishes the processes and programs required to ensure that the PWMF achieves its safety objectives and continuously monitors its performance against these objectives, and fosters a healthy safety culture. CNSC staff rated this SCA as "satisfactory" throughout the current licence period.

3.2.1 Management System

35. The Commission considered OPG's management system and CNSC staff's verification that OPG had managed the PWMF in compliance with regulatory requirements. OPG submitted detailed information regarding its management system, noting that OPG's nuclear safety policy had been approved by the OPG Board of Directors and that the Board took an active interest in ensuring that this policy was implemented.

36. OPG also submitted to the Commission that the organizational responsibilities, interfaces, and program elements were outlined in the *Nuclear Management System Charter*, whereas procedural elements of waste management were addressed in the *Nuclear Waste Management Program*. CNSC staff confirmed the information provided by OPG.

37. CNSC staff informed the Commission that OPG had consolidated and updated in 2013 the governing documentation that described OPG's management system in relation to the licensed activities at the PWMF. CNSC staff also confirmed to the Commission that OPG had successfully implemented N286-12, *Management System Requirements for Nuclear Facilities*.[9]

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[9] N286-12: *Management system requirements for nuclear facilities*, CSA Group, 2012.

38. Based on the information provided, the Commission is satisfied that OPG has an appropriate management system in place for the PWMF.

3.2.2 Organization

39. The Commission reviewed the information provided by OPG regarding the PWMF organizational structure and responsibilities, noting that day-to-day operations were handled by the Operations Manager. OPG submitted that organizational changes were managed through a change control process in conformity with CNSC regulations.

40. OPG provided the Commission with information on its management of contractors, noting that OPG had extensive experience in the use of contractors at its facilities. OPG also reported that contractors at the PWMF were qualified by the OPG Supply Chain Quality Services and that OPG ensured that contractors implemented a management system in accordance with N286-12.

41. CNSC staff confirmed the information provided by OPG and informed the Commission that, following a thorough review of OPG's organizational structure, changes within the OPG corporate structure did not result in changes to the PWMF organizational structure nor did they have an impact on the safe operation of the PWMF.

42. Based on the information considered for this hearing, the Commission is satisfied that OPG has an appropriate organizational structure in place at the PWMF to ensure continued safety of persons and the environment throughout the proposed licence period.

3.2.3 Safety Culture

43. The Commission considered the programs that OPG has in place to maintain a healthy safety culture at the PWMF. OPG submitted information to the Commission regarding its safety culture which included a Nuclear Safety Culture Assessment conducted in 2015. OPG reported that the assessment showed that there was a healthy nuclear safety culture within OPG's Nuclear Waste Management division. OPG also noted that in 22 years of operation, there had not been a single lost-time accident at the PWMF.

44. OPG reported on several initiatives that it had undertaken to further monitor safety culture at OPG facilities including the development of a new safety culture survey which will include the assessment of OPG staff's use of event-free tools. OPG noted that the nuclear safety culture at the PWMF would again be assessed in 2018, in conformance with the three-year cycle required by OPG's Nuclear Safety Culture Assessment Procedure.

45. CNSC staff confirmed the information provided by OPG and informed the Commission that an assessment of OPG's management system and documentation found that these were adequate to foster, monitor and implement improvements to the safety culture at the PWMF. CNSC staff also indicated that OPG was operating safely and was in compliance with N286-12.

46. Based on the information examined for this hearing, the Commission is satisfied that OPG has maintained and will continue to maintain a strong safety culture at the PWMF.

3.2.4 Performance Assessment

47. The Commission considered the methods used by OPG to assess performance at the PWMF. The OPG representative informed the Commission that OPG used independent audits and assessments, as well as industry peer groups, to assess performance at the PWMF.

48. CNSC staff confirmed the information provided by OPG and informed the Commission that it would continue to monitor OPG's performance through regular oversight activities including onsite inspections and desktop reviews. CNSC staff also reported that OPG had met regulatory requirements in regard to performance assessment at the PWMF.

49. Based on the information provided on the record for this hearing, the Commission is satisfied that OPG is adequately assessing performance at the PWMF.

3.2.5 Conclusion on Management System

50. Based on its consideration of the information presented on the record for this hearing, the Commission concludes that OPG has in place the appropriate organizational and management structures and that the operating performance at the PWMF during the current licence period provides a positive indication of OPG's ability to adequately carry out the activities under the proposed renewed licence.

3.3 Human Performance Management

51. Human performance management encompasses activities that enable effective human performance through the development and implementation of processes that ensure licensee staff is sufficient in number in all relevant job areas and have the necessary knowledge, skills, procedures and tools in place to safely carry out their duties. CNSC staff reviewed OPG's Human Performance Management SCA and rated it as "satisfactory" during the current licence period.

52. The Commission considered the information submitted by OPG in regard to its annual human performance assessments. OPG submitted that, through these assessments, it sought to build on past experience, determine gaps, and identify corrective actions.

53. The OPG representative informed the Commission that there had been no Site Event Free Day Resets[10] during the current licence period and that the three human performance events that were reportable to the CNSC were determined to be minor and handled appropriately, with corrections put in place to prevent their reoccurrence.

54. CNSC staff confirmed the information provided by OPG and submitted that compliance and verification activities showed that OPG had implemented, maintained and would continue to maintain during the proposed renewed licence period an effective human performance program that met regulatory requirements.

3.3.1 Personnel Training

55. The Commission assessed OPG's personnel training programs, with OPG submitting that its personnel training plans had been developed using the Systematic Approach to Training-based (SAT) process. OPG also submitted details on its training programs including procedural use and adherence, observation and coaching, pre and post-job briefings, and situational awareness.

56. CNSC staff confirmed to the Commission that OPG had a robust and documented SAT-based personnel training program in place which met the specifications of REGDOC-2.2.2.[11] CNSC staff also provided the Commission with information regarding the compliance activities, including two focussed inspections that it had carried out in 2013 and 2016 in respect of OPG's training programs, noting that these programs were found to be well-managed and appropriate for the activities being conducted at the PWMF.

57. Having examined all of the information provided on the record for this hearing, the Commission is satisfied that OPG has appropriate training programs in place at the PWMF and meets the objectives of REGDOC-2.2.2.

3.3.2 Conclusion on Human Performance Management

58. Based on its consideration of the presented information, the Commission concludes that OPG has appropriate programs in place and that current efforts related to human performance management provide a positive indication of OPG's ability to adequately carry out the activities under the proposed licence.

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[10] "Site Event Free Day Resets" are an event tracking tool. These refer to the occurrence of any event that resets the department event-free site clock, helping to track and establish lessons learned from these events.
[11] CNSC Regulatory Document REGDOC-2.2.2, *Personnel Training*, December 2016.

3.4 Operating Performance

59. The Commission examined operating performance at the PWMF, which includes an overall review of the conduct of the licensed activities and the activities that enable effective performance as well as improvement plans and significant future activities at the PWMF. During the current licence period, CNSC staff rated OPG's performance as "satisfactory" from 2008 to 2010 and as "fully satisfactory" for the remainder of the licence period.

3.4.1 Conduct of Licensed Activity

60. The Commission considered OPG's operating practices during the current licence, which included DSC operations, quality inspections and the management of storage areas. OPG submitted that it operated the PWMF in accordance with its licensing basis, licence conditions and operational standards during the current licence period. OPG also informed the Commission about the operational performance at the PWMF during the current licence period, noting that production targets were met without any lost-time accidents. CNSC staff confirmed the information provided by OPG.

61. OPG submitted that the PWMF would meet the specifications of N292.0-14, *General principles for the management of radioactive waste and irradiated fuel*,[12] N292.2-13, *Interim dry storage of irradiated fuel*[13] and N292.3-14, *Management of low- and intermediate-level radioactive waste*[14] by October 31, 2017. CNSC staff confirmed the adequacy of OPG's plans to implement these CSA Group standards.

62. OPG informed the Commission that efficiencies within the DSC production processes were being continually implemented in order to meet future DSC loading targets without compromising safety.

63. CNSC staff submitted information about the compliance activities that CNSC staff conducted in respect of the PWMF during the current licence period. Specifically, CNSC staff provided the Commission with information on high-level waste operations and construction activities at the PWMF. CNSC staff submitted that, based on its compliance activities, it was of the opinion that OPG's operation of the PWMF provided for safe and secure operation with adequate regard for the health, safety, and security of persons, the environment, and Canada's international obligations.

64. CNSC staff reported that its regulatory focus during the proposed licence period would be directed at the review and approval of documentation for the proposed construction projects at the PWMF, as well as the review and verification of implemented work management processes.

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[12] N292.0-14, *General principles for the management of radioactive waste and irradiated fuel*, CSA Group, 2014.
[13] N292.2-13, *Interim dry storage of irradiated fuel*, CSA Group, 2013.
[14] N292.3-14, *Management of low- and intermediate-level radioactive waste*, CSA Group, 2014.

65. Having examined the information submitted for this hearing, the Commission is satisfied that the PWMF was operated and will continue to be operated safely.

3.4.2 Reporting and Trending

66. The Commission assessed the information submitted by CNSC staff regarding OPG's PWMF reporting program, noting that CNSC staff were of the opinion that the program exceeded regulatory requirements.

67. CNSC staff submitted that, during the current licence period, OPG did not report any significant events to the CNSC in regard to PWMF operations. CNSC staff also submitted that OPG filed ten low safety significant event reports pursuant to sections 29 and 30 of the *General Nuclear Safety and Control Regulations*[15] (GNSCR) during the current licence period. CNSC staff further explained that there were no adverse effects on the health or safety of persons or the environment resulting from these events, that OPG had responded with appropriate actions and that all of these matters had been closed to the satisfaction of CNSC staff.

68. The Commission considered the intervention from Lake Ontario Waterkeeper, in which the intervenor opined that some OPG reporting to the CNSC appeared to be mandatory, while other reporting appeared to be discretionary, and that the reasoning behind the categorization of this reporting was not clear. The Lake Ontario Waterkeeper representative also noted that Appendix A, *Public Information Disclosure and Transparency Protocol* of OPG's public information program[16] was discretionary and did not provide a list of mandatory reports that had to be filed by OPG.

69. Further on this topic and in consideration of this concern from the Lake Ontario Waterkeeper, the Commission sought clarification about OPG's reporting requirements in relation to release events at the PWMF and on licensee public reporting requirements. CNSC staff informed the Commission that licensees were required to have a public information program that met the specifications of RD/GD-99.3, *Public Information and Disclosure*.[17] CNSC staff also explained that RD/GD-99.3 included considerations for the development of an appropriate public information and disclosure protocol for the host community and that any additional reporting that a licensee did was discretionary. The OPG representative informed the Commission about OPG's *Public Information Disclosure and Transparency Protocol*, as detailed in Appendix A of its public information program, noting that the protocol required OPG to report on all events which could result in public interest or concern within one day of the occurrence of such an event. The OPG representative asserted OPG's commitment to its *Public Information Disclosure and Transparency Protocol* and provided information regarding the environmental reports that were posted on the OPG corporate website on a quarterly basis.

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[15] SOR/2000-202.
[16] Ontario Power Generation, Nuclear Public Information and Disclosure (N-STD-AS-0013, R007), s 1.1.2
[17] CNSC Regulatory Document/Guidance Document RD/GD-99.3, *Public Information and Disclosure*, March 2012.

70. Based on the information provided, the Commission is satisfied that OPG met and will continue to meet reporting requirements throughout the proposed licence period.

71. The Commission is also satisfied that OPG understands that public information disclosure relates to the information about PWMF operations that could be of interest to members of the public whereas reporting requirements relate to information that OPG is required to report to the CNSC in accordance with CNSC regulations.

3.4.3 Proposed Construction Projects and Improvements to PWMF Operations

72. The Commission considered information submitted by OPG in respect of its construction projects to improve the efficiency of PWMF operations in order to meet future waste management requirements. These construction projects include

- the construction of a new DSC Processing Building to replace the existing facility and to increase DSC processing capability from 50 DSCs to 100 DSCs per year
- the construction of three new DSC storage buildings (#4, #5 and #6) to support the proposed continued Pickering NGS operations[18] (the construction of DSC Storage Building #4 was authorized by the Commission under the current licence but was not constructed during the current licence period)

73. In response to the intervention from Northwatch, the Commission enquired about OPG's current used fuel processing schedule and about any constraints that may exist in this schedule. The OPG representative informed the Commission that, with current capability and with the proposed facilities, the removal of all irradiated fuel from the Pickering NGS irradiated fuel bays (IFB) could be carried out by 2035. OPG further explained that the fuel had to remain in the IFBs for approximately 10 years in order for it to cool sufficiently prior to its placement into DSCs. CNSC staff confirmed the information provided by OPG and further informed the Commission that the safety of the IFBs at the Pickering NGS had been assessed and that CNSC staff was of the opinion that there were no safety issues that would require the irradiated fuel to be removed from the IFBs before the end of the 10-year fuel cooling period. The Commission is satisfied that the schedule that OPG has in place for the management of used fuel at the PWMF is appropriate.

74. Noting that OPG did not carry out any processing of nuclear substance waste at the PWMF, the Commission requested clarification about the apparent discrepancy in terminology in respect of OPG's request for authorization to construct a new and larger DSC Processing Building to replace the current one. CNSC staff responded that all fuel waste was contained within the DSCs prior to their transfer to the PWMF, that the term

[18] On May 31, 2016, OPG submitted a notice of its intent to renew the Pickering PROL for a ten-year licence period (2018-2028).

processing applied only to the work conducted on the DSCs before and after they were loaded with the fuel waste and did not involve the processing of any nuclear substances. The OPG representative confirmed the information provided by CNSC staff, provided information about the operations carried out in respect of the DSCs at the PWMF and stated that no nuclear substances or used fuel waste were processed in the DSC Processing Building. The Commission is satisfied that OPG does not carry out the licensed activity of processing nuclear substances, as defined in paragraph 26(b) of the NSCA,[19] in the DSC Processing Building at the PWMF.

75. The Commission notes the misunderstanding that the use of the term "processing" caused during these proceedings, including the interventions from Lake Ontario Waterkeeper and Northwatch, in respect to the activities that OPG carries out at the PWMF. While the Commission is satisfied with the information provided by CNSC staff and OPG in this regard and recognizes that nuclear substances are not processed at the PWMF DSC Processing Building, the Commission recommends that OPG provide additional clarity in this regard in future documentation.

3.4.4 Conclusion on Operating Performance

76. Based on the information provided on the record for this hearing, the Commission concludes that the operating performance at the PWMF during the current licence period provides a positive indication of OPG's ability to carry out the activities, including the construction of the proposed DSC Processing Building and the DSC storage buildings #3, #4 and #5 under the proposed renewed licence.

3.5 Safety Analysis

77. The Commission assessed safety analysis at the PWMF, which includes a systematic evaluation of the potential hazards associated with the conduct of a licensed activity or the operation of a facility and considers the effectiveness of preventive measures and strategies in reducing the effects of such hazards. The safety analysis supports the overall safety case for the PWMF. CNSC staff rated this SCA as "satisfactory" from 2008 to 2010 and "fully satisfactory" for the remainder of the current licence period.

3.5.1 Hazard Analysis

78. The Commission considered information provided by OPG regarding its assessment of possible malfunctions and accidents at the PWMF during key operational stages including on-site transfer operations, operations inside the DSC Processing Building and storage. OPG also submitted that its hazard analysis considered the occurrence of

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[19] S.C. 1997, c. 9, p. 26(b): Subject to the regulations, no person shall, except in accordance with a licence mine, produce, refine, convert, enrich, **process**, **reprocess**, …"

natural events such as seismic events and floods.

79. OPG submitted that the hazard analysis evaluated design provisions and procedural measures that could prevent an event or mitigate its consequences. OPG further submitted to the Commission results from the hazard analyses noting that, for all events considered in the hazard analysis, the potential doses to persons or harm to the environment were assessed to be well below regulatory levels.

80. OPG provided the Commission with information about the detailed safety assessments that OPG would perform for the three additional buildings for which OPG requested approval to construct, should the Commission approve this request.

81. CNSC staff confirmed the information provided by OPG and reported that OPG reviewed the accuracy and validity of the PWMF Safety Report at least every five years. CNSC staff also provided information about several assessments, including ERAs, which OPG had conducted to assess the safety of its operations.

82. OPG submitted information regarding updates and improvements that were being made to its safety assessment methodology to ensure that the methodology remained as accurate and up-to-date as possible. OPG further reported that it expected to use these safety assessment methodology improvements for the 2018 PWMF Safety Report update.

83. CNSC staff informed the Commission that, during the current licence period, OPG had been required to re-examine its safety case in light of the 2011 Fukushima Daiichi accident. CNSC staff reported that OPG undertook improvements and enhancements in this regard and that all activities stemming from the re-examination of the PWMF safety case had been completed to the satisfaction of CNSC staff.

84. Based on the information submitted on the record for this hearing, the Commission is satisfied that OPG's hazard analyses for the PWMF were adequate to evaluate and mitigate residual risks at the PWMF. The Commission expects OPG to carry out the appropriate safety assessments for any new buildings that OPG constructs at the PWMF site.

3.5.2 Criticality Safety

85. The Commission considered information submitted by OPG regarding the criticality assessments that had been completed for the used CANDU fuel stored in the DSCs at the PWMF. OPG submitted that assessments had shown that there could be no criticality of used fuel under normal or under postulated accident conditions at the PWMF. CNSC staff confirmed the information provided by OPG and further explained that, since the used fuel stored at the PWMF could not become critical in air or water, OPG was not required to maintain a nuclear criticality safety program for the PWMF.

86. Based on the information assessed, the Commission is satisfied that there could be no criticality of used CANDU fuel at the PWMF and that a nuclear safety criticality program at the PWMF is not required.

3.5.3 Conclusion on Safety Analysis

87. On the basis of the information presented, the Commission concludes that the systematic evaluation of the potential hazards and the preparedness for reducing the effects of such hazards are adequate for the operation of the PWMF and the activities under the proposed renewed licence.

3.6 Physical Design

88. The Commission considered the physical design of the PWMF, including the activities to design the systems, structures and components to meet and maintain the design basis of the facility. The design basis is the range of conditions, according to established criteria, that the facility must withstand without exceeding authorized limits for the planned operation of safety systems. CNSC staff rated OPG's performance in this SCA as "satisfactory" throughout the current licence period.

89. The Commission assessed the information provided by OPG regarding its physical design program. OPG submitted that the physical design program for the PWMF complied with the safety basis for the facility and that all changes were authorized and performed in a controlled manner and in accordance with the OPG licence. The OPG representative also informed the Commission that future construction at the PWMF would be compliant with new or revised codes and standards.

90. CNSC staff confirmed the information provided by OPG and informed the Commission that the physical design program at the PWMF met regulatory requirements. CNSC staff also reaffirmed to the Commission that it would continue to review all of OPG's documentation in respect of physical design changes against applicable codes and standards and that CNSC staff would monitor physical design program implementation through the conduct of compliance verification activities.

91. OPG submitted that the pressure boundary program for the PWMF met the specifications of N285.0, *General requirements for pressure-retaining systems and components in CANDU nuclear power plants*.[20] CNSC staff confirmed this information and reported that CNSC staff had verified that OPG continued to maintain a formal agreement with the Technical Standards and Safety Authority as the authorized inspection agency in this regard.

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[20] N285.0, *General requirements for pressure-retaining systems and components in CANDU nuclear power plants*, 2008 Updates No. 1 and 2, and 2012 Update No. 1, CSA Group, 2008 and 2012.

92. Asked about OPG's practice of freezing the effective dates for design-related codes and standards, the OPG representative responded that this practice was used to enable the implementation of a consistent program for all of OPG's facilities, including its waste management facilities. The OPG representative added that the practice of freezing the effective dates for codes and standards was granted to OPG on the basis that code-over-code reviews were undertaken for any subsequent work and that annual reviews were conducted. CNSC staff confirmed the information provided by OPG and also explained that, in general, codes were frozen to ensure that standard processes were in place during periods of change or major projects such as refurbishment. CNSC staff further reported that OPG used new codes and standards for new equipment but not for existing equipment that was being repaired and/or replaced. The Commission was satisfied with the information provided on this point.

3.6.1 Conclusion on Physical Design

93. On the basis of the information presented, the Commission concludes that OPG continues to implement and maintain an effective design program at the PWMF and that the design of the PWMF is adequate for the operation period included in the proposed renewed licence.

3.7 Fitness for Service

94. Fitness for Service covers activities that are performed to ensure the systems, components and structures at the PWMF continue to effectively fulfill their intended purpose. CNSC staff rated OPG's performance in this SCA as "satisfactory" throughout the current licence period.

95. OPG submitted that it was committed to maintaining PWMF systems, structures, equipment and components that were critical to the safe, reliable and economic transportation, processing and storage of nuclear waste in a fit-for-service state.

96. OPG provided the Commission with information about its equipment reliability program and the system performance monitoring that was performed on critical PWMF systems to ensure ongoing reliable operation.

97. CNSC staff confirmed the information provided by OPG and reported to the Commission that OPG had processes in place to monitor the physical condition of DSCs and PWMF components and that compliance verification activities had shown that OPG's fitness for service programs met CNSC regulatory requirements.

98. The Commission considered the information submitted by OPG regarding its preventive maintenance program, which ensured that maintenance activities were planned, scheduled and executed as required. OPG reported that the maintenance program was routinely assessed, with its status reported to PWMF management. OPG

also reported that, as part of system maintenance monitoring, corrective actions were provided to PWMF management for approval and monitored to completion. CNSC submitted to the Commission that compliance verification activities had shown that OPG appropriately scheduled, tracked and conducted preventive and corrective maintenance tasks at the PWMF.

3.7.1 Aging Management

99. The Commission considered the information provided by OPG and CNSC staff about OPG's aging management program for the PWMF. OPG provided the Commission with detailed information about its DSC and dry storage module (DSM) aging management programs and about future aging management activities that would be undertaken at the PWMF. CNSC staff confirmed the information provided by OPG and reported that OPG's aging management program met the specifications of RD-334, *Aging Management*.[21]

100. OPG reported to the Commission that, to address aging management issues at the PWMF, OPG would update the DSC and DSM aging management plans to reflect information from recently-conducted condition assessments and best practices. Additionally, OPG reported that it would update during the proposed licence period the list of safety-related systems, structures and components for the PWMF to facilitate the identification of which of these would be subjected to aging management evaluations and actions. OPG further submitted that it would implement REGDOC-2.6.3, *Aging Management*[22] at the PWMF in July 2017.

101. The Commission requested additional details about the inspection of fitness for service of DSCs. The OPG representative responded that an extensive aging program was in place at the PWMF and that a percentage of DSCs were visually inspected annually, with the inspection results reported to CNSC staff. The OPG representative also provided additional information about the corrosion monitoring of the DSCs' inner lining, noting that results had shown that the observed level of internal corrosion will not impact the lifespan of the DSCs.

102. Based on the information provided for this hearing, the Commission is satisfied that OPG has an appropriate aging management plan in place at the PWMF.

[21] CNSC Regulatory Document RD-334, *Aging Management*, June 2011.
[22] CNSC Regulatory Document REGDOC-2.6.3, *Aging Management*, March 2014.

3.7.2 Conclusion on Fitness for Service

103. Based on the information provided by OPG and CNSC staff on the record for this hearing, the Commission is satisfied with OPG's programs for the inspection and life-cycle management of key safety systems at the PWMF. Based on the above information, the Commission concludes that the equipment as installed at the PWMF is fit for service and that appropriate programs are in place to ensure that the equipment remains fit for service throughout the proposed licence period.

3.8 Radiation Protection

104. As part of its evaluation of the adequacy of the measures for protecting the health and safety of persons, the Commission considered the past performance of OPG in the area of radiation protection. The Commission also considered the radiation protection program in place at the PWMF to ensure that radioactive contamination and radiation doses to persons are monitored, controlled and kept As Low As Reasonably Achievable (ALARA), with social and economic factors taken into consideration. Throughout the current licence period, CNSC staff rated OPG's performance in this SCA as "satisfactory."

105. The Commission considered the information provided by OPG and CNSC staff to assess whether OPG's radiation protection program at the PWMF satisfied the *Radiation Protection Regulations*.[23] OPG submitted information regarding the implementation of the radiation protection program at the PWMF, noting that OPG had established a comprehensive radiation protection program to protect workers and the public. The program elements were designed to keep exposures ALARA, to implement control of public and occupational exposures, and to plan for unusual occurrences.

106. CNSC staff submitted that, throughout the current licence period, OPG implemented an appropriate and effective radiation protection program at the PWMF that satisfied regulatory requirements. CNSC staff confirmed they would continue to monitor OPG's performance in this area through ongoing regulatory oversight activities.

107. OPG submitted information to the Commission about a 2015 corporate-wide radiation protection audit, during which no major non-conformances specific to the PWMF had been identified. OPG further submitted that a corporate-level action plan in respect of improvements in the implementation of radiation protection fundamentals was put in place. CNSC staff confirmed this information and submitted to the Commission that CNSC staff would closely monitor these initiatives during the proposed renewed licence period.

[23] SOR/2000-203.

3.8.1 Application of ALARA

108. The Commission assessed the information submitted by OPG and CNSC staff regarding the application of the ALARA principle at the PWMF. OPG submitted that, in keeping with the ALARA principle, individual and collective doses were well below regulatory and administrative limits throughout the current licence period and that ALARA planning was performed for all work conducted at the PWMF.

109. CNSC staff reported to the Commission that OPG's radiation protection program met the specifications of G-129, *Keeping Radiation Exposures and Doses "As Low As Reasonably Achievable" (ALARA).*[24] CNSC staff confirmed to the Commission that OPG's radiation protection program for the PWMF integrated ALARA into planning, scheduling, and work controls and established and monitored performance against ALARA targets for work conducted at the PWMF. CNSC staff also noted that OPG generated ALARA targets on a yearly basis based on the volume of radioactive waste to be handled at the PWMF.

110. Based on the information considered for this hearing, the Commission is satisfied that the ALARA concept is adequately applied to all PWMF activities.

3.8.2 Worker Dose Control

111. OPG submitted to the Commission that worker doses during the current licence period were consistently below OPG's exposure control levels and well below the regulatory limits established by the CNSC. The OPG representative also noted that the maximum effective dose received by a worker during the current licence period was 3.2% of the regulatory dose limit. CNSC staff confirmed that worker radiation doses at the PWMF had been maintained well below regulatory limits.

112. CNSC staff submitted that OPG used CNSC-licensed dosimetry services to monitor, assess, record and report doses of ionizing radiation received by employees, visitors and contractors as a result of activities at the PWMF, with doses for individual reported to the National Dose Registry.

113. CNSC staff informed the Commission that, in keeping with the ALARA principle, OPG had planned improvements to its radiation protection program during the proposed renewed licence period and CNSC staff would be closely monitoring these initiatives.

114. The Commission considered a written submission from the Power Workers' Union, which included workers at the PWMF. In its submission, the Power Workers' Union informed the Commission that OPG had a comprehensive health and safety framework

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[24] CNSC Regulatory Guide G-129, *Keeping Radiation Exposures and Doses "As Low As Reasonably Achievable" (ALARA)*, Revision 1, October 2004.

in place, including a Joint Committee on Radiation Protection, to protect workers at the PWMF.

115. Based on the information provided for this hearing, the Commission is satisfied that doses to workers at the PWMF are adequately controlled.

3.8.3 Control of Dose to the Public

116. The Commission considered the effectiveness of OPG's programs to prevent uncontrolled releases of contaminants or radioactive materials to the public from the PWMF. OPG reported to the Commission about the methods by which it controlled dose to the public throughout the current licence period. OPG submitted that the estimated dose for members of the public was well below the regulatory annual public dose limit of 1 mSv[25] throughout the current licence period.

117. CNSC staff confirmed that the estimated dose to the public from PWMF operations remained well below regulatory requirements throughout the current licence period. Noting that the PWMF was at the site border of the Pickering NGS, CNSC staff also submitted that the dose contribution from PWMF operations was a small fraction of the estimated dose to the public from the overall Pickering site.

118. The Commission enquired about the appropriateness of the action levels that were used by OPG for radiation protection. CNSC staff explained the purpose of action levels and further stated that action levels were assessed by CNSC staff during a licensing review to ensure that they were appropriate in the context of the proposed activities. CNSC staff further reported to the Commission that its assessment in this regard had not yet been finalized. The Commission expects CNSC staff to finalize the review of radiation protection action levels as soon as possible during the proposed licence period.

119. The Commission requested additional information about action level management, derived release limits[26] (DRL) and how the public could use this data to assess dose information. CNSC staff responded that this issue of how the public could interpret action levels and DRLs was recognized within the industry and that novel ways of considering action levels to ensure that they were performance and data-based was being considered through a new CSA Group standard. The Commission was satisfied with the information provided on this point and looks forward to the new CSA Group Standard.

120. Based on the information provided for this hearing, the Commission is satisfied that OPG is adequately controlling radiological doses to the public from the PWMF

[25] The regulatory dose limit for a member of the public is 1 mSv (1,000 μSv) per year and the natural background dose is estimated between 2 mSv – 5 mSv (2,000 μSv – 5,000 μSv) per year.

[26] The derived release limit for a given radionuclide is the release rate that would result in an annual committed effective radiation dose of 1 mSv to the most exposed group of the public (also known as the critical receptor) for that nuclear substance.

operations.

3.8.4 Conclusion on Radiation Protection

121. Based on the information provided on the record for this hearing, the Commission concludes that, given the mitigation measures and safety programs that are in place and will be in place to control radiation hazards, OPG provides, and will continue to provide, adequate protection to the health and safety of persons and the environment throughout the proposed renewed licence period.

122. The Commission is satisfied that OPG's radiation protection program at the PWMF meets the requirements of the *Radiation Protection Regulations*.

3.9 Conventional Health and Safety

123. The Commission examined OPG's implementation of a conventional health and safety program at the PWMF to manage workplace safety hazards. This program is mandatory for all employers and employees in order to reduce the risks associated with conventional (non-radiological) hazards in the workplace. This program includes compliance with Part II of the *Canada Labour Code*[27] and conventional safety training. Throughout the current licence period, CNSC staff rated OPG's performance in this SCA as "satisfactory" from 2008 to 2010 and "fully satisfactory" for the balance of the current licence period.

124. The Commission notes that, in addition to the NSCA and its regulations, OPG's activities and operations must comply with the *Canada Labour Code*, Part II: *Occupational Health and Safety* and that OPG must report to the Province of Ontario on any reports made to other regulatory bodies under the *Occupational Health and Safety Act of Ontario*[28] and the *Labour Relations Act, 1995*.[29]

125. OPG submitted to the Commission that it had a Conventional Safety Program in place at the PWMF to ensure and promote a healthy and injury-free workplace. OPG also submitted that it had managed the PWMF without a lost-time accident throughout its entire operational life of 22 years.

126. CNSC staff confirmed to the Commission that OPG had a conventional health and safety program at the PWMF that exceeded regulatory requirements throughout the current licence period. CNSC staff further submitted that no areas of concern in respect of OPG's conventional health and safety program for the PWMF had been identified during on-site inspections by CNSC staff.

[27] R.S.C., 1985, c. L-2.
[28] R.S.O., 1990, c. O.1.
[29] S.O., 1995, c. 1, Sched. A.

127. OPG provided the Commission with information regarding its Employee Health and Safety Policy and Internal Responsibility System which had as its objective to prevent workplace injuries and ill health, to improve employee health and safety performance and for each employee to take initiative in regard to workplace health and safety. OPG also reported that it had implemented the corporate-level “iCare” program in 2016, which had as a goal to further enhance conventional health and safety by increasing OPG staff’s commitment to individual and group awareness of safety issues.

128. OPG provided the Commission with information regarding conventional health and safety improvements planned for the proposed renewed licence period. OPG submitted that these improvements would be undertaken as continuous improvement activities and would aim to increase situational awareness, implement improved tools for OPG staff and implement a Total Health Initiative. CNSC staff confirmed the information on these improvements and submitted that, during the proposed licence period, CNSC staff would verify their implementation through documentation reviews and inspections.

129. In response to the Commission’s enquiry for details about the iCare program, the OPG representative explained that, although the full scope of the program was still under development, it was considered to be an important tool to engage employees in safety issues. The OPG representative also stated that the iCare program was closely associated with human performance tools such as peer coaching. In terms of measuring the success of the iCare program, the OPG representative stated that safety trends would be assessed and evaluated. The Commission is satisfied with the information provided on the iCare program and encourages OPG to continue its efforts in this regard.

130. The Commission considered an intervention from the Power Workers’ Union, which reported to the Commission that OPG and its workers had in place a comprehensive health and safety framework that protected workers. The Power Workers’ Union submitted that this framework included a Joint Policy Committee on Health and Safety and a Joint Health and Safety Working Committee.

131. The Commission concludes that the health and safety of workers and the public was adequately protected during the operation of the facility for the current licence period and that the health and safety of persons would also be adequately protected during the continued operation of the facility in the proposed renewed licence period.

3.10 Environmental Protection

132. The Commission examined OPG’s environmental protection programs at the PWMF, under which OPG identifies, controls and monitors all releases of radioactive and hazardous substances, and aims to minimize the effects on the environment which may result from the licensed activities. These programs include effluent and emissions control, environmental monitoring and estimated doses to the public. CNSC staff rated

OPG’s performance in this SCA as “satisfactory” throughout the current licence period.

133. The Commission considered whether the PWMF environmental protection programs adequately met the specifications of REGDOC-2.9.1, *Environmental Protection Policies, Programs and Procedures*.[30]

3.10.1 Effluent and Emissions Control (Releases)

134. The Commission considered OPG’s programs to control the release of effluent and emissions from the PWMF to the environment. OPG submitted that monitoring results from its effluent and emissions control programs showed that effluent and emissions releases were within regulatory limits and that the systems were performing as designed.

135. OPG also submitted information about groundwater monitoring for the PWMF that was integrated with the Pickering NGS site groundwater monitoring program. OPG reported that an assessment of the groundwater flow, conducted in the 2003 Pickering NGS site EA, found that there would be no likely effects to the environment from groundwater originating from the PWMF, including from the construction activities related to the proposed DSC processing and storage buildings.

136. CNSC confirmed the information provided by OPG and reported that OPG’s plans to implement N288.7-15, *Groundwater protection programs at Class I nuclear facilities and uranium mines and mills*[31] and N288.1-14, *Guidelines for calculating derived release limits for radioactive material in airborne and liquid effluents for normal operation of nuclear facilities*[32] by December 31, 2017 were adequate.

137. CNSC staff further submitted to the Commission that, through an assessment of OPG’s effluent monitoring program, it was of the opinion that adequate measures were in place to protect the public and the environment from releases from the PWMF.

138. The Commission, considering the concerns from Lake Ontario Waterkeeper, enquired about the timing and frequency of groundwater sampling. The OPG representative responded that groundwater monitoring had been in place for 17 years at the site, that the site was sampled semi-annually and that the flow migration was well understood with no concerns noted. The Commission is satisfied that groundwater sampling at the PWMF site is adequate.

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[30] CNSC Regulatory Document REGDOC-2.9.1, *Environmental Protection Policies, Programs and Procedures*, 2013.

[31] N288.7-15, *Groundwater protection programs at Class I nuclear facilities and uranium mines and mills*, CSA Group, 2015.

[32] N288.1-14, *Guidelines for calculating derived release limits for radioactive material in airborne and liquid effluents for normal operation of nuclear facilities*, CSA Group, 2014.

139. The Commission, in its consideration of Lake Ontario Waterkeeper's intervention, enquired about tritium releases from the PWMF. CNSC staff informed the Commission that tritium releases from the PWMF were below the internal investigation levels at the PWMF. CNSC staff further asserted that, based on its review of the intervention in question, no clear trend relating to an increase in tritium emissions was evident. CNSC staff explained that, as part of risk-based regulation, CNSC staff had determined that a follow-up in regard to tritium emissions from the PWMF was not required. Based on the information provided, the Commission is satisfied that, at this time, tritium emissions from the PWMF are not increasing. The Commission, however, expects CNSC staff to provide an updated and confirmatory analysis in this regard in the next ROR.

140. Further on the topic of tritium releases from the PWMF, the Commission sought clarification regarding the assertion from Lake Ontario Waterkeeper that these releases resulted in "significant adverse effects" to the environment. CNSC staff informed the Commission that no tritium was processed at the PWMF and that CNSC staff's review of the EA and ERA revealed no impacts to the environment near the PWMF. OPG also informed the Commission that none of the proposed new construction projects at the PWMF would be processing tritium. The Commission is satisfied that the PWMF is not a major contributor to tritium in the environment at and near the Pickering NGS site. Further, the Commission is satisfied that, although the Pickering NGS contributes to tritium releases near the site, OPG is and will continue to appropriately control these releases in the proposed licence period and that these releases do not have an adverse effect on the environment.

141. In reference to the intervention from Northwatch about liquid waste sampling, the Commission asked OPG for clarification in this regard. The OPG representative responded that liquid waste sampling was now carried out monthly. The OPG representative acknowledged that, for approximately 10 years prior to 2011, this sampling was undertaken only every 26 weeks but that this has since been rectified. CNSC staff confirmed that liquid waste sampling was now conducted monthly at the Pickering NGS site and was reported quarterly. The Commission is satisfied that adequate liquid waste sampling is now being carried out at the facility and expects this frequency of liquid waste sampling to continue in the proposed licence period.

142. On the issue of hydrazine releases from the PWMF, as raised by Northwatch in its intervention, CNSC staff informed the Commission that, although there could be controlled releases of hydrazine from the Pickering NGS, this was not the case for the PWMF. The Commission is satisfied that the hydrazine releases are not an issue that requires consideration in this licensing matter.

143. On the basis of the information provided for this hearing, the Commission is satisfied that OPG has and will continue to have adequate programs in place for the control of effluent and emissions at the PWMF to protect the environment and meet regulatory requirements. The Commission encourages OPG to continue its efforts of continuous

improvement in this regard.

144. The Commission expects OPG to implement the updated standards for effluent and emissions control programs at the PWMF as per the timelines submitted during this hearing.

3.10.2 Environmental Management System

145. The Commission assessed the information provided by OPG and CNSC staff in respect of the OPG Environmental Management System (EMS). OPG submitted that it had implemented a corporate-wide EMS which established annual objectives and that these would be verified through internal and compliance audits. OPG also submitted that its EMS was ISO 14001[33] certified.

146. CNSC staff informed the Commission that it had verified that OPG's EMS met the specifications of REGDOC-2.9.1. CNSC staff also informed the Commission that it had verified that annual management reviews of the EMS had taken place and that corrective actions had been documented.

147. Based on the information provided, the Commission is satisfied that OPG has maintained, and will continue to maintain, an adequate EMS at the PWMF.

3.10.3 Assessment and Monitoring

148. The Commission considered information submitted by OPG about OPG's environmental monitoring program that is designed to demonstrate that emissions from the site are properly controlled. OPG informed the Commission that emissions from the PWMF were monitored under the Pickering Nuclear Environmental Monitoring Program, which included emissions from the entire Pickering NGS site. OPG also reported that emission monitoring from the site included off-site air, water and terrestrial samples and that monitoring data were used to assist in determining the dose to the public living or working near the Pickering NGS site. OPG further submitted that doses to the public from the PWMF were a small fraction of the public dose limit.

149. The Commission also considered CNSC staff's EA Report for this licence renewal. CNSC staff confirmed the effluent and emission monitoring results reported by OPG and informed the Commission that assessment and monitoring confirmed that radioactive releases from the PWMF are well within regulatory limits and non-radioactive releases were negligible.

150. CNSC staff reported that OPG's environmental monitoring programs met the specifications of N288.4-10, *Environmental monitoring program at Class I nuclear*

[33] ISO 14001, *Environmental Management Systems*, International Organization for Standardization.

facilities and uranium mines and mills, and that OPG's environmental monitoring programs met CNSC requirements.

151. The Commission requested additional information about the implementation of OPG's environmental monitoring program. CNSC staff explained that the implementation of an environmental monitoring program was a licensing requirement and that CNSC staff ensured that the OPG's environmental monitoring program met licence and regulatory requirements through its oversight activities.

152. In its consideration of the intervention from Lake Ontario Waterkeeper, the Commission requested additional information from OPG regarding its storm water monitoring. The OPG representative responded that OPG carried out storm water monitoring for the Pickering NGS site and reported on the gross beta-gamma activity in rainwater discharged from the facility. OPG provided the Commission with detailed information regarding surface drainage from the PWMF Phase I and II sites and further submitted that the impact of the PWMF's operation on storm water runoff was negligible since there were no liquid effluent discharges from the PWMF into the storm water system. Based on the information provided by OPG and on results from EAs and ERAs, the Commission is satisfied that the PWMF's impact on storm water runoff from the Pickering NGS site is adequately characterized by OPG and is negligible.

153. The Commission requested clarification in regard to the annual airborne release information, from 2008 to 2016, that was submitted by CNSC staff in the EA Report. CNSC staff provided additional details in regard to the airborne release information characterized in the EA report. The Commission directs CNSC staff to provide this information more clearly in future submissions.

Independent Environmental Monitoring Program

154. The Commission examined the information provided by CNSC staff in regard to the CNSC's Independent Environmental Monitoring Program (IEMP). CNSC staff provided results from monitoring that was carried out in 2014 and 2015 in publicly accessible areas outside the perimeter of the Pickering NGS site, which includes the PWMF, and noted that the measured radioactivity in all samples was below CNSC reference levels.[34]

155. CNSC staff submitted that the 2014 and 2015 IEMP results showed that the public and the environment around the Pickering NGS site, which included the PWMF, were protected and that there should be no health or environmental impacts. CNSC staff further reported that the IEMP results were consistent with the environmental monitoring results submitted by OPG, demonstrating that OPG's environmental protection program continued to protect the health of persons and the environment.

[34] CNSC reference levels are established based on conservative assumptions about the exposure scenario and using N288.1-14. On this basis, the reference level for a particular radionuclide in a particular medium represents the activity concentration that would result in a dose of 0.1 mSv per year.

156. The Commission enquired about the concern expressed by Northwatch in regard to the location of sampling points for the CNSC's Independent Environmental Monitoring Program (IEMP). CNSC staff provided the Commission with details regarding the IEMP sampling locations for food and surface water near the Pickering NGS site and noted that the IEMP did not include groundwater since the IEMP only considered publicly-accessible areas outside the facility site. CNSC staff explained that surface water was monitored at five locations through the IEMP and that the sampling information properly characterized releases from the facility. CNSC staff further explained that, although groundwater was not sampled through the IEMP, CNSC staff regularly reviewed the results of and conducted inspections on OPG's groundwater monitoring program. The Commission is satisfied that sampling points for the IEMP were appropriately considered by CNSC staff to characterize the environment near the Pickering NGS site.

157. Based on the information submitted by CNSC staff in the EA Report, the Commission is satisfied that the EA adequately shows that OPG made and will continue to make adequate provision for the protection of the environment and persons at the PWMF site.

158. The Commission is satisfied that OPG's and the CNSC's environmental monitoring show that the public and the environment around the PWMF site remain protected.

3.10.4 Protection of the public

159. The Commission assessed OPG's programs to mitigate risk to members of the public from hazardous substances discharged from the PWMF. OPG submitted that results of monitoring and public dose assessment were published in the Pickering NGS annual Environmental Monitoring Program report which is submitted to the CNSC and made available to the public through OPG's corporate website.

160. CNSC staff informed the Commission that, since 2008, there had been no reportable spills to the environment and no environmental infractions at the PWMF.

161. Based on the information provided, the Commission is satisfied that OPG's programs to mitigate risk to members of the public from PWMF operations are adequate.

3.10.5 Environmental Risk Assessment

162. The Commission considered information about the 2014 and 2017 ERAs that were completed by OPG for the entire Pickering NGS site, including the PWMF. OPG submitted that the ERAs characterized the baseline environment and assessed risks to the environment from the operations at the Pickering NGS site. OPG also submitted that the ERAs also evaluated the risks to people and the environment, and identified areas that would require further monitoring or assessment. OPG reported to the Commission that the 2014 ERA had identified a number of areas where supplementary

studies were recommended in order to clarify risk and reduce uncertainty in regard to operations at the entire Pickering NGS site, but noted that the object of the supplementary studies were not related to PWMF operations.

163. CNSC staff confirmed the information provided by OPG and submitted that the 2014 and 2017 ERAs complied with all applicable requirements and provided a complete evaluation of all potential risks to human health and the environment associated with the operations at the Pickering NGS site.

164. CNSC staff submitted that the 2017 ERA for the Pickering NGS met the specifications of N288.6-12 and regulatory requirements. CNSC staff also submitted that the 2014 and 2017 ERAs showed that meaningful human health or ecological effects attributable to operations at the PWMF were unlikely and that OPG had and continued to make adequate provision for the protection of the environment and the health of persons.

165. The Commission considered the interventions from the Lake Ontario Waterkeeper and Northwatch in regard to the 2014 and 2017 ERAs that were submitted following the April 13, 2017 oral hearing. The Commission notes the intervenors' concerns in regard to the ERAs including, but not limited to, the consideration of groundwater, as well as the exposure pathways to human receptors to site groundwater, the sampling locations used, and the characterization of releases from the Pickering NGS facility. In this regard, and based on all submissions received in this matter, the Commission is satisfied that intervenors' concerns have been adequately considered in the ERAs carried out for the Pickering NGS site.

166. Based on the information presented on the record for this hearing, the Commission is satisfied that the ERAs were carried out satisfactorily and showed that OPG was adequately protecting the environment in the vicinity of the Pickering NGS, and therefore, the PWMF site.

167. The Commission expresses its dissatisfaction that the 2014 ERA was not made publicly available for the April 13, 2017 oral hearing and directs OPG make future ERAs available to the public as soon as practicable.

3.10.6 Conclusion on Environmental Protection

168. Based on the assessment of the application and the information provided on the record at the hearing, the Commission is satisfied that, given the mitigation measures and safety programs that are in place to control hazards, OPG will provide adequate protection to the health and safety of persons and the environment throughout the proposed licence period.

169. The Commission asks that CNSC staff and licensees/applicants use less ambiguous terminology such as "very minor percentage" in submissions to the Commission. The Commission directs CNSC staff to provide the Commission with clarification in regard

to what is represented by “very minor percentage” and expects that, in future submissions to the Commission, terminology with a higher degree of accuracy will be used.

170. In regard to tritium emissions, the Commission expects CNSC staff to provide an updated and confirmatory analysis in the next NPP ROR in regard to the tritium outlier data that was presented in the Lake Ontario Waterkeeper intervention.

171. The Commission directs CNSC staff and OPG to present information regarding annual airborne releases more clearly in future submissions to the Commission and to the public.

3.11 Emergency Management and Fire Protection

172. The Commission considered OPG’s emergency management and fire protection programs which cover the measures for preparedness and response capabilities implemented by OPG in the event of emergencies and non-routine conditions at the PWMF. This includes nuclear emergency management, conventional emergency response and fire protection response. Throughout the current licence period, CNSC staff rated OPG’s performance in this SCA as “satisfactory.”

3.11.1 Emergency Management

173. The Commission considered the information provided by OPG and CNSC staff about OPG’s emergency management program at the PWMF. OPG submitted that the Pickering NGS Emergency Response Team (ERT) was the primary responder for the PWMF Phase I. OPG further submitted that the City of Pickering was the primary responder for PWMF Phase II and that the Pickering NGS ERT was the secondary responder for Phase II. OPG also reported to the Commission about the emergency response drills and exercises that OPG conducts with local emergency response partners and about hazardous material spill drills, including nuclear spills, that are regularly carried out at the PWMF.

174. OPG informed the Commission that, following the Fukushima Daiichi accident, OPG re-examined the safety case for the PWMF including defence-in-depth concepts that included external hazards (seismic, flooding, fire and extreme weather events), measures for accident prevention and mitigation, as well as emergency preparedness. OPG submitted safety case improvements that had been carried out at the PWMF during the current licence period including design basis and beyond design basis events.

175. CNSC staff confirmed the information provided by OPG and submitted that OPG’s emergency management program for the PWMF met regulatory requirements and met

the specifications of RD-353, *Testing and Implementation of Emergency Measures*.[35] CNSC staff also submitted that, during the proposed renewed licence period, OPG had committed to implement REGDOC-2.10.1, *Nuclear Emergency Preparedness and Response*[36] by December 31, 2018.

176. The Commission requested additional information about OPG's capabilities, as supported by outside agencies, to adequately respond to emergency situations at the PWMF. The OPG representative provided the Commission with additional detailed information about the emergency management plan at the PWMF and about the support that would be provided by emergency response personnel from the Pickering NGS and the City of Pickering, if required. OPG also provided information about the emergency exercises that it conducted on a regular basis and which involved outside agencies and organizations. CNSC staff informed the Commission that OPG's mutual aid capability had been carefully assessed and that CNSC staff were of the opinion that the necessary resources would be available for an extended emergency situation. The Commission is satisfied that OPG has appropriate emergency management resources to mitigate an accident at the PWMF.

177. Based on the information provided on the record for this hearing, the Commission is satisfied with OPG's programs to manage emergencies at the PWMF. The Commission expects OPG to implement REGDOC-2.10.1 at the PWMF by December 31, 2018.

3.11.2 Fire Protection

178. The Commission examined the adequacy of the PWMF fire protection program. OPG submitted that the fire protection and detection systems at the PWMF were designed and constructed to comply with applicable codes and standards, including the *National Fire Code of Canada* (NFC),[37] the *National Building Code of Canada* (NBC),[38] and N285.0-08, Update 1, *General requirements for pressure-retaining systems and components in CANDU nuclear power plants*.[39] OPG also provided information regarding the OPG Engineering Change Control process for design modifications and how inspections, testing and maintenance of the fire protection system were carried out in accordance with the PWMF licence.

179. OPG submitted that, in 2012, an independent third-party review of OPG's fire protection program at the PWMF showed that the program fulfilled CNSC licensing requirements and complied with or met the specifications of applicable codes and standards. OPG also provided the Commission with information regarding internal audits of the PWMF fire protection program and how corrective actions were identified

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[35] CNSC Regulatory Document RD-353, *Testing and Implementation of Emergency Measures*, 2008.
[36] CNSC Regulatory Document REGDOC-2.10.1, *Nuclear Emergency Preparedness and Response*, 2016.
[37] Reference 2005
[38] Reference 2005
[39] N285.0-08, Update 1, *General requirements for pressure-retaining systems and components in CANDU nuclear power plants*, CSA Group, 2008.

and implemented throughout the current licence period.

180. CNSC staff confirmed the information provided by OPG and explained that CNSC staff had verified that OPG had implemented and maintained a program at the PWMF for fire protection to minimize both the probability of occurrence and the consequence of fire at the facility.

181. OPG submitted to the Commission that, in the proposed renewed licence period, OPG would implement the 2010 versions of the NBC and NFC, as well as N393-13, *Fire protection for facilities that process, handle or store nuclear substances.*[40]

182. Based on the information provided, the Commission is satisfied that OPG has an adequate fire protection program in place at the PWMF that meets regulatory requirements. The Commission expects OPG to implement the updated codes and standards at the PWMF during the proposed renewed licence period.

3.11.3 Conclusion on Emergency Management and Fire Protection

183. Based on the above information, the Commission concludes that the fire protection measures and emergency management preparedness programs in place, and that will be in place, at the PWMF are adequate to protect the health and safety of persons and the environment.

3.12 Waste Management

184. The Commission considered the PWMF waste management program which covers the waste generated during the operations of the PWMF. Throughout the current licence period, CNSC staff evaluated OPG performance in this SCA with regards to waste minimization and management practices as "satisfactory."

185. OPG submitted to the Commission that its waste management program was aligned with and based on the OPG nuclear environmental management program, and that it implemented strategies for waste minimization and management. OPG also provided information about waste management procedures used at the PWMF and submitted that minimal radioactive waste was generated from the activities carried out at the PWMF, with a maximum amount of one drum of low-level waste sent to the Pickering NGS annually for segregation as necessary. OPG further reported that no intermediate- or high-level waste was generated at the PWMF.

186. CNSC staff confirmed the information provided by OPG and submitted that OPG had implemented and maintained a program at the PWMF for waste management to minimize the generation of waste at the facility and dispose of wastes and by-products

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[40] N393-13, *Fire protection for facilities that process, handle or store nuclear substances*, CSA Group, 2013.

in accordance with CNSC regulatory requirements. CNSC staff further reported that the PWMF's waste management program met the specifications of N292.2-07, *Interim dry storage of irradiated fuel*[41] and N292.3-08, *Management of low- and intermediate-level radioactive waste*.[42]

187. OPG reported that, should OPG's request to construct a new DSC Processing Building be authorized, the waste volume generated at the site was expected to increase due to increased processing of DSCs. OPG confirmed, however, that the waste volume generated at the PWMF would remain low. CNSC staff confirmed that the volume of waste generated at the PWMF would not increase significantly with increased processing of DSCs, that the waste generated would remain low-level and that OPG would continue to adequately manage the waste generated at the PWMF.

188. CNSC staff reported that OPG would implement N292.0-14, *General principles for the management of radioactive waste and irradiated fuel*,[43] N292.2-13, *Interim dry storage of irradiated fuel*[44] and N292.3-14, *Management of low- and intermediate-level radioactive waste*[45] by October 31, 2017, which was acceptable to CNSC staff.

189. Based on the above information and consideration of the hearing materials, the Commission is satisfied that OPG has appropriate programs in place to safely management waste at the PWMF.

190. The Commission is satisfied that the increased DSC processing capacity that would be provided with the new DSC Processing Building would not significantly increase the waste originating from the PWMF.

191. The Commission expects OPG to implement the latest versions of applicable standards in accordance with the schedule in the proposed LCH and submitted during this hearing.

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[41] N292.2-07, *Interim dry storage of irradiated fuel*, CSA Group, 2007.
[42] N292.3-08, *Management of low- and intermediate-level radioactive waste*, CSA Group, 2008.
[43] N292.0-14, *General principles for the management of radioactive waste and irradiated fuel*, CSA Group, 2014.
[44] N292.2-13, *Interim dry storage of irradiated fuel*, CSA Group, 2013.
[45] N292.3-14, *Management of low- and intermediate-level radioactive waste*, CSA Group, 2014.

3.13 Security

192. The Commission examined OPG's security program at the PWMF, which is required for OPG to implement and support the security requirements stipulated in the relevant regulations and the operating licence. This includes compliance with the applicable provisions of the *General Nuclear Safety and Control Regulations*[46] and the *Nuclear Security Regulations*.[47] CNSC staff rated OPG's performance in this SCA as "satisfactory" from 2008 to 2010 and as "fully satisfactory" from 2011 to 2016.

193. OPG provided the Commission with information about the OPG security program and explained that key elements of the program included response to threats and maintaining compliance with legislative requirements, while minimizing the adverse impact on staff and PWMF operations. OPG submitted that the objective of its security program was to establish a state of security readiness to ensure safe and secure operation of OPG facilities.

194. OPG reported to the Commission that the information about security programs and procedures submitted in support of this licence renewal application applied to both Phases I and II of the PWMF. OPG submitted that PWMF Phase I was located within the Pickering NGS protected area and that the security arrangements in Phase I were the same as those for the Pickering NGS. In respect of PWMF Phase II, OPG submitted that it was located within a separate protected area of the Pickering NGS controlled area site.

195. OPG informed the Commission that its security program for the PWMF met requirements of the *Nuclear Security Regulations,* as well as the specifications of RD-321, *Criteria for Physical Protection Systems and Devices at High-Security Sites*,[48] RD-363, *Nuclear Security Officer Medical, Physical and Psychological Fitness*,[49] RD-361, *Criteria for Explosive Substance Detection, X-Ray Imaging and Metal Detection Device at High-Security Site*,[50] and REGDOC-2.12.2, *Site Access Security Clearance*.[51]

196. CNSC staff confirmed the information provided by OPG and further submitted that OPG had measures in place to effectively prevent theft or sabotage of nuclear material in use, storage, or transport at the PWMF and that OPG's programs exceeded regulatory requirements. CNSC staff reported that OPG had formal arrangements with the Durham Regional Police Service for offsite armed response. CNSC staff also

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[46] SOR/2000-202.
[47] SOR/2000-209.
[48] CNSC Regulatory Document RD-321, *Criteria for Physical Protection Systems and Devices at High-Security Sites*, 2010.
[49] CNSC Regulatory Document RD-363, *Nuclear Security Officer Medical, Physical and Psychological Fitness*, 2008.
[50] CNSC Regulatory Document RD-361, *Criteria for Explosive Substance Detection, X-Ray Imaging and Metal Detection Devices at High-Security Sites*, 2010.
[51] REGDOC-2.12.2, *Site Access Security Clearance*, 2013.

submitted information regarding inspections that had been carried out during the current licence period, noting that identified corrective actions had been implemented and closed to the satisfaction of CNSC staff.

197. OPG informed the Commission that, through a threat and risk assessment, OPG had determined that an onsite nuclear response force at the PWMF was not required due to the robustness of the DSCs. OPG also provided detailed information regarding enhancements that had been made to the security program at the PWMF and the Pickering NGS during the licence period and submitted that an assessment carried out by OPG showed that OPG's programs met the specifications of REGDOC-2.12.3, *Security of Nuclear Substances – Sealed Sources*[52] in relation to Category 1, 2 and 3 sealed sources. OPG further informed the Commission that its programs would be compliant with REGDOC-2.12.3 in respect of Category 4 and 5 sources by May 31, 2018.

198. OPG submitted information regarding the improvements that it had carried out to its nuclear security program during the current licence period and about planned improvements for the proposed renewed licence period, including the expansion of the PWMF protected area. CNSC staff confirmed the adequacy of the security program improvements as proposed by OPG, noting that they represented continuous improvement in OPG's security programs and that these improvements considered the expansion of the PWMF Phase II through the proposed construction projects.

199. OPG provided the Commission with information regarding its cybersecurity programs and submitted that these programs protected the cyber-critical assets for nuclear safety, physical protection and emergency preparedness functions from cyberattacks.

200. In its consideration of the intervention from Northwatch, the Commission enquired about whether security implications resulting from the transport of used fuel in the DSCs to the proposed DSC processing facility had been considered. CNSC staff responded that the transfer of used fuel was conducted only within the Pickering NGS site boundary and that all such activities were escorted by nuclear security officer personnel. CNSC staff also explained that security issues such as this one had been satisfactorily considered and addressed at the Pickering NGS and PWMF sites and that a CNSC-approved transport security plan had to be in place prior to the transport of any used fuel. The Commission is satisfied that the security considerations for the transport of used nuclear fuel have been satisfactorily addressed by OPG.

201. Further considering the intervention from Northwatch, the Commission requested additional information regarding the possibility of malevolent acts at the PWMF. CNSC staff informed the Commission that OPG had produced design basis threat documentation that comprehensively outlined potential sabotage and theft of nuclear material scenarios. CNSC staff further submitted that OPG had demonstrated to the satisfaction of CNSC staff its capacity to mitigate such scenarios through CNSC

[52] REGDOC-2.12.3, *Security of Nuclear Substances – Sealed Sources*, 2013.

inspections and through nuclear security exercises.

202. The Commission asked about whether remote control of the transport vehicles had been planned or was planned for the future. The OPG representative responded that remote operations had not been used for operations at the PWMF site and that none were planned.

203. The Commission enquired about security-related incidents that had occurred at the PWMF during the current licence period. CNSC staff informed the Commission that four security-related events occurred during the licence period between 2009 and 2013. CNSC staff further elaborated that these events had been minor in nature and were now closed. CNSC staff also clarified that there had been no security-related events at the PWMF since 2013. The Commission is satisfied with the information provided on this point.

204. On the basis of the information provided on the record for this hearing, the Commission is satisfied that OPG's performance with respect to maintaining security at the facility has been acceptable. Therefore, the Commission concludes that OPG has made adequate provision for the physical security of the PWMF, and is of the opinion that OPG will continue to make adequate provision for security during the proposed licence period.

205. The Commission expects OPG to make the improvements to its security program at the PWMF as was proposed during this hearing.

3.14 Safeguards and Non-Proliferation

206. The CNSC's regulatory mandate includes ensuring conformity with measures required to implement Canada's international obligations under the *Treaty on the Non-Proliferation of Nuclear Weapons* (NPT). Pursuant to the Treaty, Canada has entered into safeguards agreements with the International Atomic Energy Agency (IAEA). The objective of these agreements is for the IAEA to provide credible assurance on an annual basis to Canada and to the international community that all declared nuclear material is in peaceful, non-explosive uses and that there is no undeclared nuclear material or activities in this country. CNSC staff rated OPG's performance in this SCA as "satisfactory" throughout the current licence period.

207. The Commission considered the effectiveness of OPG's implementation of safeguards measures and non-proliferation commitments related to the activities at the PWMF. OPG provided the Commission with information on the OPG safeguards program and how IAEA safeguards were implemented at the PWMF. OPG submitted that, since 2012, the PWMF fully met the specifications of RD-336, *Accounting and Reporting of Nuclear Material*,[53] noting that OPG had updated its *Nuclear Fuel Location and*

[53] CNSC Regulatory Document RD-336, *Accounting and Reporting Nuclear Material*, 2010.

Storage History (NuFLASH) program to support its implementation of RD-336. OPG also submitted that its programs met the specifications of GD-336, *Guidance for Accounting and Reporting of Nuclear Material*.[54]

208. CNSC staff confirmed that OPG had an effective safeguards program in place at the PWMF that satisfied regulatory requirements and provided the Commission with information regarding safeguards compliance verification. CNSC staff also submitted information regarding CNSC and IAEA inspections that had been carried out throughout the current licence period at the PWMF, noting that all corrective actions had been satisfactorily addressed by OPG and had been closed.

209. OPG submitted that it would replace the DSC metal seal system with the IAEA-designed Laser Mapping Container Verification System, should it be approved for use in Canada, during the proposed licence period. CNSC staff also informed the Commission that OPG would be improving its safeguards program during the proposed licence period through the implementation of an electronic fuel inventory reporting system.

210. Based on the above information, the Commission is satisfied that OPG has provided for, and will continue to provide for, adequate measures in the areas of safeguards and non-proliferation at the PWMF that are necessary for maintaining national security and measures necessary for implementing international agreements to which Canada has agreed.

3.15 Packaging and Transport

211. The Commission examined OPG's packaging and transport program at the PWMF. Packaging and transport covers the safe packaging and transport of nuclear substances and radiation devices to and from the licensed facility. The licensee must adhere to the *Packaging and Transport of Nuclear Substances Regulations, 2015*[55] (PTNSR 2015) and Transport Canada's *Transportation of Dangerous Goods Regulations*[56] (TDG Regulations) for all shipments leaving the facility. During the current licence period, CNSC staff rated OPG's performance in this SCA as "satisfactory."

212. OPG submitted information to the Commission about its transportation program at the PWMF, noting that all transportation of nuclear material to or from the PWMF was carried out in accordance with OPG's Nuclear Radioactive Material Transportation program. OPG further submitted that at the Pickering NGS site, all transport of low- and intermediate-level waste off-site was carried out under the Pickering NGS Nuclear Power Reactor Operating Licence and that there was no shipment of used CANDU fuel directly from the PWMF.

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[54] CNSC Guidance Document GD-336, *Guidance for Accounting and Reporting of Nuclear Material*.
[55] SOR/2015-145.
[56] SOR/2001-286.

213. OPG reported that used fuel in DSCs was transferred on-site under the PWMF WFOL from the IFBs to the PWMF and submitted that 835 loaded DSCs had been safely transferred from the Pickering NGS to the PWFM since 1996. OPG also provided the Commission with information demonstrating that, in over 43 years of transporting radioactive material on public roads, there had not been an accident resulting in a release of radioactive material or serious personal injury.

214. CNSC staff confirmed the information provided by OPG and informed the Commission that OPG's packaging and transport program at the PWMF met regulatory requirements. CNSC staff submitted that OPG had put into service a new DSC transporter vehicle in 2013 and that its use met all regulatory requirements.

215. CNSC staff clarified for the Commission that the PTNSR 2015 applied only during the transport of nuclear substances on public roads. CNSC staff added that on-site transfer of nuclear substances was covered by the operating licence and noted that restrictions applied to these transfer activities, including the limitation on transfer during severe weather conditions and vehicle speed limits.

216. Northwatch, in its intervention, noted that information in respect of the consequences of a DSC drop was not found in OPG's submissions for this hearing; the Commission requested additional information in this regard. The OPG representative responded that drop scenarios had been thoroughly investigated, both at the Pickering NGS, where the fuel was placed into DSCs, and at the PWMF, where OPG carried out the final processing and storage of the DSCs. CNSC staff also explained that DSCs were certified transport containers and had been tested against applicable certification requirements in that regard, including withstanding a 9 metre drop. The OPG representative added that DSCs were only raised 15 to 20 cm above the ground during transport. The Commission is satisfied that drop scenarios have been adequately considered by OPG for its transport activities.

217. The Commission enquired about quality control measures that were used for DSC manufacturing to ensure their robustness during transport activities. The OPG representative responded that OPG had an extensive quality control program in place that considered many aspects of DSC manufacturing including welds and the quality of steel used. The OPG representative also noted that OPG required that the DSC manufacturer be qualified in accordance with Z299.2-85, *Quality Assurance Program Category 2*,[57] the main quality assurance program applied in respect of DSC manufacturing activities. The OPG representative added that OPG conducted its own audits during DSC manufacturing activities to ensure their compliance with relevant codes and standards. The Commission is satisfied with the information provided on this point.

[57] Z299.2-85 (R2007), *Quality Assurance Program Category 2*, CSA Group, 2007.

218. Based on the information presented on the record for this hearing, the Commission is satisfied that OPG is meeting, and will continue to meet, regulatory requirements regarding packaging and transport.

3.16 Aboriginal Engagement and Public Information

3.16.1 Participant Funding Program

219. The Commission assessed the information provided by CNSC staff regarding public engagement in the licensing process as enhanced by the CNSC's Participant Funding Program (PFP). CNSC staff submitted that, in November 2016, up to $50,000 in funding to participate in this licensing process was made available to Indigenous groups, not-for-profit organizations and members of the public to review OPG's licence renewal application and associated documents, and to provide the Commission with value-added information through topic-specific interventions.

220. A Funding Review Committee (FRC), independent of the CNSC, recommended that four applicants be provided with $42,251 in participant funding. These applicants were required, by virtue of being in receipt of participant funding, to submit a written intervention and make an oral presentation at the public hearing commenting on OPG's licence renewal application. One PFP applicant withdrew its request prior to the hearing. As such, $35,699 in participant funding was awarded to the following recipients:

- Northwatch
- Lake Ontario Waterkeeper
- Women in Nuclear Canada (WiN-Canada)

3.16.2 Aboriginal Engagement

221. The common law duty to consult with Aboriginal peoples applies when the Crown contemplates action that may adversely affect established or potential Aboriginal and/or treaty rights. The CNSC, as an agent of the Crown and as Canada's nuclear regulator, recognizes and understands the importance of building relationships and engaging with Canada's Aboriginal peoples. The CNSC ensures that all of its licensing decisions under the NSCA uphold the honour of the Crown and considers Aboriginal peoples' potential or established Aboriginal and/or treaty rights pursuant to section 35 of the *Constitution Act, 1982*.[58]

222. The Commission examined the information submitted by OPG regarding its ongoing engagement with Indigenous groups near the PWMF site. OPG submitted that its corporate-wide Indigenous Relations policy provided a framework for engaging with

[58] *Constitution Act, 1982*, Schedule B to the *Canada Act 1982*, 1982, c. 11 (U.K.).

Indigenous Peoples and supporting community programs and initiatives. OPG confirmed its commitment to its engagement with Indigenous groups about PWMF nuclear waste operations and future operations.

223. OPG informed the Commission that its Indigenous Relations program met the specifications of REGDOC-3.2.2, *Aboriginal Engagement*[59] and provided the Commission with detailed information regarding the Indigenous engagement activities that OPG had undertaken throughout the current licence period. CNSC staff confirmed the information provided by OPG and submitted that OPG Indigenous engagement approach for the PWMF, including the regular provision of information and PWMF site tours, met CNSC staff expectations.

224. OPG reported that it participated in the Canadian Council for Aboriginal Business' Progressive Aboriginal Relations program in 2015 which identified opportunities to enhance the Indigenous procurement process and Indigenous recruitment. OPG further reported that these improvements would be implemented in 2017 and that OPG's Progressive Aboriginal Relations assessment would assist OPG in taking additional measures to improve its Indigenous Relations program.

225. CNSC staff submitted that OPG's *Aboriginal Engagement Report* described how OPG had undertaken engagement with identified Indigenous communities with asserted or established Aboriginal and treaty rights or interests in the PWMF project area and whose rights may be potentially affected by the proposed activity. OPG and CNSC staff provided the Commission with details regarding issues that were raised by Indigenous groups during this relicensing process, including emergency preparedness, environmental monitoring and environmental impacts of the PWMF, with CNSC staff submitting that OPG addressed these issues in accordance with CNSC expectations.

226. The Commission requested additional information regarding any outstanding issues arising from OPG's Indigenous engagement activities. The OPG representative indicated that through its engagement activities with the Indigenous groups that had been identified to have a primary interest in OPG's operations at the PWMF, OPG was not aware of any outstanding issues, including those related to the impact of PWMF operations on fish. The OPG representative explained that the impacts of the PWMF on fish was initially a major issue raised by Indigenous groups and that there were no outstanding issues that OPG was aware of in that regard.

227. CNSC staff provided the Commission with information about eight Indigenous groups and affiliated organizations that had been identified by the CNSC which may have an interest in the proposed PWMF licence renewal and about the consultation activities that CNSC staff carried out with the identified groups. CNSC staff also explained that, based on the information provided in OPG's licence renewal application and the Aboriginal engagement activities completed by OPG, CNSC staff determined that a consultation approach that was considered low on the duty to consult spectrum was

[59] CNSC Regulatory Document REGDOC-3.2.2, *Aboriginal Engagement*, 2016.

appropriate. CNSC staff submitted to the Commission that CNSC's consultation approach included identifying Aboriginal communities with potential or established Aboriginal or treaty rights that could be adversely affected by the activities proposed in the licence renewal application. CNSC staff then notified each of the identified communities and affiliated organizations of CNSC's licensing review, provided information on how to participate in the review process including the Commission hearing, the availability of participant funding, and provided a copy of OPG's application.

228. CNSC staff submitted that communication with interested Indigenous groups was, and would continue to be, maintained throughout the proposed licence period to ensure that the groups received all information requested and to establish and maintain relationships with the groups.

229. The Commission noted that Indigenous groups did not submit interventions for this hearing and requested additional information about the information provided to Indigenous groups regarding the opportunity to participate in this hearing process. CNSC staff provided the Commission with details regarding the information that was provided to and follow-ups that were carried out with the eight identified Indigenous groups, noting that several groups had indicated that they were not interested in participating in this hearing. CNSC staff also stated that several Indigenous groups had informed CNSC staff that they would continue to engage directly with OPG on matters of mutual interest and that CNSC staff was of the opinion that OPG had carried out adequate engagement to encourage participation in regarding to this licence renewal process and that OPG would continue to adequately engage with Indigenous groups. The Commission was satisfied that OPG and CNSC staff made adequate efforts to provide Indigenous groups with information about the possibility of participation during this licence renewal process.

230. Based on the information provided for this hearing, the Commission is satisfied that Aboriginal engagement activities carried out for this licence renewal were adequate. The Commission expect OPG to implement improvements to its Indigenous Relations program as submitted for this hearing.

3.16.3 Public Information

231. The Commission assessed OPG's public information and disclosure program (PIDP) for the PWMF. A public information program is a regulatory requirement for licence applicants and licensed operators of Class I nuclear facilities. Paragraph 3(j) of the *Class I Nuclear Facilities Regulations*.[60] requires that licence applications include

> "the proposed program to inform persons living in the vicinity of the site of the general nature and characteristics of the anticipated effects on the

[60] SOR/2000-204

environment and the health and safety of persons that may result from the activity to be licensed."

232. OPG submitted to the Commission that the PIDP for the PWMF met the specifications of RD/GD-99.3, *Public Information and Disclosure.*[61] OPG also submitted detailed information regarding its community consultation and outreach programs, disclosure protocol and improvements that OPG would bring to its PIDP in the proposed renewed licence period. CNSC staff confirmed the information provided by OPG and submitted that OPG's PIDP met regulatory requirements.

233. The Commission considered the issue submitted in Lake Ontario Waterkeeper's intervention that information required for its review of OPG's licence renewal application was difficult to obtain from both OPG and CNSC staff, and requested additional details in this regard. CNSC staff explained that, in general, all non-sensitive information related to the licence application and referenced in CMDs was provided to intervenors. However, CNSC further explained that, in general, CNSC staff did not provide intervenors with documentation prepared by the licensee but if an intervenor was having trouble getting documentation, an intervenor could contact the CNSC for assistance in this regard.

234. The Commission also considered Lake Ontario Waterkeeper's concern that it had received conflicting information on whom to contact in respect of documentation for participation in this hearing process when it was not able to obtain some of the information that it required for its review from OPG. CNSC staff informed the Commission that, in general, an intervenor should contact CNSC staff if a licensee does not provide them with documents which should have been made publicly available. The Commission expressed its dissatisfaction with this apparent confusion in the process for the provision of publicly-available information to intervenors and is of the view that any such information should be made easily available to all members of the public. The OPG representative and CNSC staff indicated to the Commission's satisfaction that they would increase efforts to ensure the provision of publicly-available documentation to intervenors in a timely manner.

235. The Commission noted that the intervention from WiN-Canada expressed that there was a lack of knowledge about several SCAs as they related to the PWMF among WiN-Canada members and called for comments in this regard. The OPG representative provided the Commission with information about the ways by which OPG had engaged with WiN-Canada in regard to the PWMF and this licence renewal application. The OPG representative acknowledged that the survey carried out by WiN-Canada as part of its intervention had identified some areas of communication, including information about environmental protection and waste management, in respect of which OPG could improve its communication with WiN-Canada and other organizations, and affirmed its commitment in this regard. The Commission is satisfied with the information provided on this point.

[61] CNSC Regulatory/Guidance Document RD/GD-99.3, *Public Information and Disclosure*, 2012.

236. The Commission acknowledged several interventions which cited PWMF site visits and requested additional information about the number of visitors the site received annually. The OPG representative responded that, on average, the PWMF site received approximately 200 to 300 visitors annually. The Commission was satisfied with the information provided on this point.

237. The Commission noted its appreciation for the written submission from the Pickering Nuclear Generating Station Community Advisory Council (CAC) which stated that the CAC's members had toured the PWMF, that facility staff had responded to CAC members' questions and that information about the PWMF was regularly communicated to the public by OPG through public meetings, with minutes of those meetings posted on the OPG public website.

238. Based on the information presented, the Commission is satisfied that OPG's PIDP has and will continue to communicate to the public information about the health, safety and security of persons and the environment and other issues related to the PWMF.

239. The Commission expressed its dissatisfaction with the difficulty several intervenors encountered in information requests for this licence renewal hearing. The Commission expects OPG and CNSC staff to review their procedures in this regard to ensure that publicly-available information is provided to the public in a timely manner.

3.16.4 Conclusion on Aboriginal Engagement and Public Information

240. Based on the information presented on the record for this hearing, the Commission is satisfied that, overall, OPG's PIDP meets regulatory requirements and is effective in keeping Indigenous groups and the public informed of OPG operations. The Commission acknowledges the many best practices already implemented by OPG and encourages OPG to continue to create, maintain and improve its dialogue with neighbouring communities.

241. The Commission acknowledges the current efforts and commitments made by OPG in relation to Aboriginal engagement and CNSC staff's efforts in this regard on behalf of the Commission. Based on the information presented on the record for this hearing, the Commission is satisfied that this licence renewal will not result in any changes to PWMF operations, that the renewal will not cause adverse impacts on potential or established Aboriginal or treaty rights, and that the duty to consult was not triggered in this matter. The Commission is also of the opinion that the engagement activities taken for the review of the PWMF licence renewal application have been adequate.[62]

[62] *Rio Tinto Alcan v. Carrier Sekani Tribal Council*, 2010 SCC 43[2010] 2 S.C.R. 650 at paras 45 and 49.

3.17 Decommissioning Plans and Financial Guarantee

242. The Commission requires that OPG has operational plans for the decommissioning of the facility and long-term management of waste produced during the life-span of the PWMF. In order to ensure that adequate resources are available for safe and secure future decommissioning of the PWMF site, the Commission requires that an adequate financial guarantee for realization of the planned activities is put in place and maintained in a form acceptable to the Commission throughout the licence period.

243. OPG submitted that its Preliminary Decommissioning Plan (PDP) for the PWMF had been prepared in accordance with N294-09, *Decommissioning of facilities containing nuclear substances*[63] and met the specifications of G-219, *Decommissioning Planning for Licensed Facilities*.[64] OPG further submitted that the PDP was updated every five years or when requested by the Commission. OPG also reported that its revised PDP would include the PWMF Phase II expansion. CNSC staff confirmed that OPG had in place for the PWMF a PDP that met regulatory requirements.

244. CNSC staff submitted that OPG had last revised its PDP in 2012 and that an updated PDP would be provided to CNSC staff by the end of 2017. CNSC staff also submitted that OPG would need to revise the PWMF PDP following the completion of approved construction activities, including the new DSC Processing Building, and DSC Storage Buildings #4, #5 and #6.

245. OPG submitted information on its decommissioning strategy for the PWMF, noting that all sources of radioactivity would be removed from the PWMF prior to its dismantlement thus greatly reducing radiation hazards and reducing the need for deferred decommissioning. OPG did note, however, that some decommissioning activities may be deferred to better align with related activities at the site. CNSC staff confirmed to the Commission that OPG's decommissioning strategy was acceptable and met regulatory requirements.

246. OPG submitted that the PWMF was included in OPG's consolidated financial guarantee for the implementation of PDPs for all of its nuclear facilities in Ontario. The Commission notes that, following a hearing held in October 2017, the Commission accepted OPG's consolidated financial guarantee for its nuclear facilities in Ontario with the understanding that it provides for the future decommissioning of the PWMF.

247. Based on the information, the Commission concludes that the PDP and related financial guarantee are acceptable for the purpose of the current application for licence renewal.

[63] N294-09, *Decommissioning of facilities containing nuclear substances*, CSA Group, 2009.
[64] CNSC Regulatory Guide G-219, *Decommissioning Planning for Licensed Facilities*, 2000.

3.18 Cost Recovery

248. The Commission examined OPG's standing under the *Cost Recovery Fees Regulations*[65] (CRFR) requirements for the PWMF. Paragraph 24(2)(c) of the NSCA requires that a licence application is accompanied by the prescribed fee, as set out by the CRFR and based on the activities to be licensed.

249. OPG submitted that, throughout the current licence period, timely cost recovery fee payments were submitted to the CNSC on a quarterly basis. CNSC staff confirmed the information provided by OPG.

250. Based on the information submitted by OPG and CNSC staff, the Commission concludes that OPG has satisfied the requirements of the CRFR for the purposes of this licence renewal.

3.19 Nuclear Liability Insurance

251. The Commission notes that OPG is required to maintain nuclear liability insurance for the PWMF. CNSC staff submitted that OPG maintained nuclear liability insurance in accordance with the *Nuclear Liability Act*[66] during the current licence period until December 31, 2016 and since then, with the *Nuclear Liability and Compensation Act*[67] (NLCA) that came into force on January 1, 2017. CNSC staff reported to the Commission that Natural Resources Canada, the federal department responsible for the administration of the NLCA, had confirmed that OPG had satisfied and should continue to satisfy its obligation under the NLCA during the balance of the current licence period and throughout the proposed licence period.

252. Based on the information provided on the record for this hearing, the Commission is satisfied that OPG has satisfied and will continue to satisfy the requirements for the maintenance of nuclear liability insurance under the NLCA. The Commission expects annual updates in the NPP ROR in regard to OPG's compliance with the NLCA.

3.20 Licence Length and Conditions

253. OPG requested the renewal of its current operating licence for the PWMF for a period of approximately 11 years, until August 31, 2028. CNSC staff recommended the renewal of the licence to August 31, 2028 and submitted that OPG is qualified to carry on the licensed activities authorized by the licence.

254. In order to provide adequate regulatory oversight of authorized changes which do not

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[65] SOR/2003-212.
[66] R.S.C., 1985, c. N-28 (repealed)
[67] S.C. 2015, c. 4, s. 120

require a licence amendment nor Commission approval, CNSC staff recommended that the Commission delegate its authority as contemplated in licence conditions 12.2 (Construction) and 15.2 (Commissioning Report), and for purposes described in the compliance verification section of the draft LCH related to LC 5.2 (Pressure Boundary) to the following CNSC staff:

- Director, Wastes and Decommissioning Division
- Director General, Directorate of Nuclear Cycle and Facilities Regulation
- Executive Vice-President and Chief Regulatory Operations Officer, Regulatory Operations Branch

255. CNSC staff also recommended that the Commission delegate its administrative authority for the purposes described in the compliance verification section of the draft LCH related to LC 13.1 (Safeguards Program) to the following staff:

- Director, International Safeguards Division
- Director General, Directorate of Security and Safeguards
- Vice-President, Technical Support Branch

256. CNSC staff submitted that that the PWMF's performance in all SCAs remained stable or improved over the current 10-year licence period and that the PWMF operated safely during this period. CNSC staff added that the annual NPP ROR, which was presented to the Commission at public proceedings with opportunity for intervention, would allow for frequent public updates regarding OPG and the PWMF's performance, as well as CNSC regulatory oversight activities as they pertained to the PWMF.

257. The Commission considered the intervention from the Regional Municipality of Durham which submitted a concern regarding the proposed 10-year licence renewal period leading to reduced opportunity for public participation. The Commission acknowledges the intervenor's concerns and wishes to clarify, on the record, that members of the public would be invited to participate and comment on the performance of the PWMF during the annual NPP ROR, presented at a public Commission meeting. In this regard, the OPG representative reaffirmed to the Commission OPG's commitment to continue enhancing the existing communications and relationship that OPG has with the Regional Municipality of Durham. The Commission is satisfied that OPG has maintained and will continue to maintain adequate communication with the Regional Municipality of Durham and other stakeholders.

258. Several intervenors, including Lake Ontario Waterkeeper and Northwatch, expressed the view that OPG's licence renewal application should be considered at the same time as the Pickering NGS licence renewal application. Intervenors noted that the PWMF was on the same site as the Pickering NGS and that environmental impacts and other operational issues of the two facilities were closely linked. The Commission recognizes the integrated nature of the operation of the PWMF and the Pickering NGS. Notwithstanding, the Commission also recognizes that the two facilities operate under separate CNSC licences and, as such, considering the licence renewals separately is

appropriate.

259. On this same topic, the Commission is of the view that the separation in the operating licences for the PWMF and Pickering NGS, which are both operated by OPG and situated on the same site, may be artificial and that consolidation of the licences into a single licence may be appropriate. The Commission notes that similar licence consolidations had been carried out for similar nuclear facilities. On this basis, the Commission invites CNSC staff and OPG to investigate the merits of the future consolidation of the PWMF WFOL and the Pickering NGS PROL.

260. The Commission noted the concerns raised by several intervenors in respect of the CNSC's reliance on external standards, such as CSA Group standards, instead of CNSC-only regulatory documents and requested additional information in this regard. CNSC staff submitted that, in addition to CNSC REGDOCs, regulatory documents and guides, CSA Group standards and guides were one of several sources of standards and guidance documents that were used to regulate nuclear facilities in Canada, ensuring a comprehensive regulatory model. CNSC staff also submitted information to the Commission about its participation in the development of CSA Group standards and other related technical committees.

261. The Commission is satisfied that the current approach of including external standards and guidance, such as CSA Group standards, in the CNSC's regulatory framework is appropriate and adequate to ensure the safety and security of nuclear facilities and the environment, and the protection of the public in Canada. In light of the questions raised by intervenors during this hearing, the Commission strongly recommends that CNSC staff provides more information on the inclusion of CSA Group and other standards in the CNSC's regulatory framework during a presentation at a future public Commission meeting.

262. Based on the above information and the information examined by the Commission for this hearing, the Commission is satisfied that a licence expiring on August 31, 2028 is appropriate for the PWMF. The Commission accepts the licence conditions as recommended by CNSC staff. The Commission also accepts CNSC staff's recommendation regarding the delegation of authority, and notes that it can bring any matter to the Commission as applicable.

4.0 CONCLUSION

263. The Commission has considered the information and submissions of the applicant, CNSC staff and all participants as set out in the material available for reference on the record, as well as the oral and written submissions provided or made by the participants, both at the oral hearing and by written submissions thereafter.

264. The Commission is satisfied that OPG meets the test set out in subsection 24(4) of the *Nuclear Safety and Control Act*. That is, the Commission is of the opinion that OPG is

qualified to carry on the activity that the proposed licence will authorize and that OPG will make adequate provision for the protection of the environment, the health and safety of persons and the maintenance of national security and measures required to implement international obligations to which Canada has agreed.

265. Therefore, the Commission, pursuant to section 24 of the *Nuclear Safety and Control Act*, renews the Waste Facility Operating Licence issued to Ontario Power Generation for its Pickering Waste Management Facility located in Pickering, Ontario. The renewed licence, WFOL-W4-350.00/2028, will be valid from April 1, 2018 until August 31, 2028.

266. The Commission includes in the licence the conditions as recommended by CNSC staff in CMD 17-H5. The Commission also delegates authority to senior CNSC staff for the purposes of licence conditions 5.2, 12.2, 13.1 and 15.2, as recommended by CNSC staff.

267. The Commission authorizes the construction activities as outlined in CMD 17-H5 and in the proposed licence. The Commission expects OPG to carry out the appropriate safety assessments for any new buildings that OPG constructs at the PWMF site. The Commission notes that OPG's requirements to carry out the proposed construction projects are primarily dependent on the continued operation of the Pickering NGS.

268. The Commission considers the environmental review that was conducted by CNSC staff to be acceptable and thorough. The Commission is satisfied that an EA under CEAA 2012 was not required for the PWMF licence renewal application or for the proposed construction projects. Further, the Commission notes that the NSCA and its regulations provide for the protection of the environment and the health and safety of persons, and is satisfied that the OPG will continue to make adequate provision in this regard.

269. With this decision, the Commission directs CNSC staff to report annually on the performance of OPG and the PWMF, as part of an annual NPP ROR. The Commission directed that CNSC staff shall present this report at a public proceeding of the Commission, where members of the public will be able to participate.

270. The Commission encourages OPG to make available to the public data on contaminants of primary concern and directs that CNSC staff report on the status of public disclosure by OPG as part of the NPP ROR.

271. The Commission expresses its dissatisfaction that the Pickering NGS 2014 ERA was not made publicly available for the April 13, 2017 oral public hearing and directs OPG make future ERAs available to the public as soon as practicable.

272. The Commission notes that CNSC staff can bring any matter to the Commission as applicable. The Commission directs CNSC staff to inform the Commission on an annual basis of any changes made to the LCH.

273. The Commission notes that following a hearing held in October 2017, the Commission accepted OPG's consolidated financial guarantee for its nuclear facilities in Ontario. Since it includes the PWMF, no additional decision is required in this regard.

M. Binder FEB 0 6 2018

Michael Binder Date

President,

Canadian Nuclear Safety Commission

Appendix A – Intervenors

Intervenors	Document Number
T. Seitz	CMD 17-H5.2
R. Rosario	CMD 17-H5.3
Regional Municipality of Durham	CMD 17-H5.4
Power Workers' Union	CMD 17-H5.5
BWXT Canada Ltd.	CMD 17-H5.6
Canadian Nuclear Laboratories	CMD 17-H5.7
Canadian Nuclear Workers' Council	CMD 17-H5.8
Canadian Nuclear Association, represented by S. Coupland	CMD 17-H5.9
Women in Nuclear Canada, represented by K. Kleb and P. Watson	CMD 17-H5.10 CMD 17-H5.10A
Lake Ontario Waterkeeper, represented by P. Feinstein	CMD 17-H5.11 CMD 17-H5.11A CMD 17-H5.11B
Pickering Nuclear Community Advisory Council	CMD 17-H5.12
Northwatch, represented by B. Lloyd	CMD 17-H5.13 CMD 17-H5.13A CMD 17-H5.13B CMD 17-H5.13C

ONTARIO POWER GENERATION

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OPG Proprietary

June 20, 2023

CD # 92896-CORR-00531-01478

MR. DENIS SAUMURE
Commission Registrar

Canadian Nuclear Safety Commission
280 Slater Street
P.O. Box 1046, Station B
Ottawa, Ontario
K1P 5S9

Dear Mr. Saumure:

OPG – Change Request Application for Amendment to the Pickering Waste Management Facility (PWMF) Waste Facility Operating Licence WFOL W4-350.00/2028

The purpose of this letter is to submit to the Canadian Nuclear Safety Commission, herein referred to as “the Commission”, a change request application for Pickering Waste Management Facility (PWMF) under Waste Facility Operating Licence (WFOL) WFOL-W4-350.00/2028, to be able to store younger than 10-year cooled fuel from the Pickering Nuclear Generating Station (PNGS). The younger fuel would have a minimum 6-year cooling period. The change request application has been drafted per the CNSC’s direction in Reference 1. OPG had previously communicated the operational need for this activity in Reference 2.

To support the OPG Safe Storage Project for Pickering Nuclear Generating Station (PNGS), additional space in the PNGS-B Irradiated Fuel Bay (IFB-B) is required in order to accept the discharged used fuel from the required core dumps. As PWMF is currently waiting for IFB-B used fuel to mature to the 10-year required period before transferring, there is a need to accept younger fuel to allow for the additional space. At this time, however, OPG is only licensed to process minimum 10-year cooled fuel at all its Nuclear Waste Facilities.

Attachment 1 describes how the licensing basis for the proposed activity, as defined in OPG’s application, will accommodate the pertinent clauses of relevant regulatory requirements.

Attachment 2 provides a description and key attributes of the storage of minimum 6-year cooled fuel and documents the licensing impact assessment on all 14 Safety and Control Areas of PWMF’s WFOL. Enclosures 1-3 are OPG documents that are being provided to support this assessment.

Enclosure 4 contains an assessment of the findings of a previously trialed Dry Storage Container containing 6-year cooled fuel in 1998. The CNSC requested this evaluation in Reference 3. Prior to that, OPG had submitted technical assessments to the CNSC related to the storage of minimum 6-year cooled fuel (References 4, 5) (Enclosures 1, 2 and 3).

The design considerations of the storage of minimum 6-year cooled fuel complies with all applicable regulatory requirements. The safety assessment, which is referred to as the “safety case”, demonstrates that the storage of minimum 6-year cooled fuel will have no significant impact on the continued safe operation of the PWMF, and on public, employee and environmental safety, as is defined in the following elements:

- **Design:** OPG has and will continue to follow its established Engineering Change Control (ECC) process for ensuring the design complies with applicable regulatory requirements and that configuration management for the station will be maintained

- **Continued Safe Operation of PWMF:** Safety analysis submitted to CNSC staff demonstrates that the storage of minimum 6-year cooled fuel will have negligible effect on the safe operation of the PWMF, and on worker and public safety.

- **Environmental Protection**: the conclusions of the PWMF Phase II EA are still considered fully valid with the storage of minimum 6-year fuel.

- **Licensing Basis**: As documented in Attachments 1 and 2, the storage of minimum 6-year cooled fuel will have a negligible impact on PWMF’s licensing basis, governance, and its well-established programs and processes.

OPG is targeting to start loading DSC’s with minimum 6-year cooled fuel in July 2024. After an initial loading of two to four DSC’s to confirm temperature and dose measurements, a full campaign of loading younger fuel will commence.

In summary, OPG remains committed to the safe operation of the PWMF and re-affirms that younger than 10-year cooled fuel can be stored safely as presented in the associated safety case.

If you have any questions, please contact Mr Cliff Barua, Senior Advisor, Regulatory Programs and Support Strategies, at (416) 526-5075 or cliff.barua@opg.com.

Sincerely,

Kapil Aggarwal

Kapil Aggarwal, M. Eng., P. Eng.
Vice President
Nuclear Sustainability Services

Enc.

cc: N. Petseva - CNSC (Ottawa)
T. Kalindjian - CNSC (Ottawa)
S. Watt - CNSC (Ottawa)
R. van Hoof - CNSC (Ottawa)

References:

1. CNSC letter, N. Greencorn to J. Van Wart, “CNSC Staff Response to OPG’s Submission – Notice of Intent to Store Minimum 6-Year Old Used Fuel at the Pickering Waste Management Facility”, April 5, 2022, 2018, CD# W-CORR-00531-01819, e-Doc 6755368.

2. OPG letter, J. Van Wart to N. Greencorn, “Notice of Intent to Store Minimum 6-Year Old Used Fuel at the Pickering Waste Management Facility”, February 1, 2022, CD# W-CORR-00531-01801.

3. CNSC letter, T. Kalindjian to K. Aggarwal, “CNSC Staff Review of OPG Responses to CNSC Staff Comments - Proposal to Store Minimum 6-Year Old Cooled Used Fuel at the Pickering Waste Management Facility”, December 20, 2021, CD#92896-CORR-00531-01443, e-Doc 6687357

4. OPG letter, K. Aggarwal to T. Kalindjian, “OPG Response to CNSC Staff Comments on OPG’s Proposal to Store Minimum 6-Year Old Cooled Used Fuel at the Pickering Waste Management Facility”, June 14, 2021, 92896-CORR-00531-01430.

5. OPG letter, K. Aggarwal to G. Steedman, “Proposal to Store Minimum 6-Year Old Used Fuel at the Pickering Waste Management Facility, November 5, 2020, CD# 92896-CORR-00531-01397, e-Doc 6416392.

List of Enclosures:

1. OPG technical memo, “Storage of Dry Storage Containers (DSCs) containing less than 10 year old used fuel bundles at the Pickering Waste Management Facility (PWMF)”, July 27, 2020, W-CORR-00531-01662

2. OPG report, “Safety Assessment Storing Lower Aged Fuel in PWMF SB3”, 92896-REP-01320-00012

3. OPG report, “Dose Rate Assessment Considering Lower Aged Fuel in PWMF SB3”, 92896-REP-03200-00009

4. OPG letter, P. Dinner to Y. Mroueh, “Additional Information Concerning: Thermal Gradients Pertaining to Dry Storage Containers (DSCs)”, May 4, 2005, 00104-CORR-79171-0139942

ATTACHMENT #1

Licence Amendment Matrix
Applicable Regulations

ATTACHMENT 1

Licence Amendment Matrix - Applicable Regulations

This Attachment, along with the accompanying letter and Attachment 2 of this submission, provides the information required by the Nuclear Safety and Control Act and the applicable Nuclear Regulations made pursuant to the Act, and constitutes an application by OPG to amend the current Pickering Waste Management Facility (PWMF) Waste Facility Operating Licence (WFOL) WFOL-W4-350.00/2028.

The tables below are divided by applicable Regulation and demonstrate how OPG has addressed each applicable regulatory requirement of the subject Regulation.

Nuclear Safety and Control Act		
Section	**Requirement**	**OPG Response**
	Licences	
24(2)	***Application*** *The Commission may issue, renew, suspend in whole or in part, amend, revoke, or replace a licence, or authorize its transfer on receipt of an application:* *(a) in the prescribed form;*	This submission (letter and attachments) provides the information required by the Nuclear Safety and Control Act (referred to as the Act) and the Regulations made pursuant to the Act and provides supplemental information in support of OPG's application for licence amendment. This requirement has been met.
	(b) containing the prescribed information and undertakings and accompanied by the prescribed documents; and	See response above under clause 24 (2) (a).
	(c) accompanied by the prescribed fee.	OPG is in good standing with respect to the provision of CNSC licensing fees and will provide any additional fees associated with this WFOL amendment request, if requested.
24(4)	***Conditions for issuance, etc.*** *No licence may be issued, renewed, amended or replaced - and no authorization to transfer one given - unless, in the opinion of the Commission, the applicant:*	OPG understands that qualification will be determined through consideration by the Commission of this application and the associated supporting material, as well as deliberation through the Commission decision-making process.

Nuclear Safety and Control Act		
Section	**Requirement**	**OPG Response**
	(a) is qualified to carry on the activity that the licence will authorize the licensee to carry on; and	OPG is qualified to safely undertake the additional activities associated with the storage of minimum 6-year cooled fuel at PWMF.
	(b) will, in carrying on that activity, make adequate provision for the protection of the environment, the health and safety of persons and the maintenance of national security and measures required to implement international obligations to which Canada has agreed.	Attachment 2 of this submission documents the assessments and provisions in support of the licence amendment request. Specifically: • documents worker health and safety provisions. • documents assessments and impact on environmental protection. • documents the security considerations. • documents the impact on Canada's international obligations related to safeguards and non-proliferation.
25	***Renewal, etc.*** *The Commission may, on its own motion, renew, suspend in whole or in part, amend, revoke or replace a licence under the prescribed conditions.*	OPG understands this requirement and will continue to comply.

Nuclear Safety and Control Act		
Section	**Requirement**	**OPG Response**
26	***Prohibitions*** *Subject to the regulations, no person shall, except in accordance with a licence:* *(a) possess, transfer, import, export, use or abandon a nuclear substance, prescribed equipment or prescribed information;* *(b) mine, produce, refine, convert, enrich, process, reprocess, package, transport, manage, store or dispose of a nuclear substance;* *(c) produce or service prescribed equipment;* *(d) operate a dosimetry service for the purposes of this Act;* *(e) prepare a site for, construct, operate, modify, decommission or abandon a nuclear facility; or* *(f) construct, operate, decommission or abandon a nuclear-powered vehicle or bring a nuclear-powered vehicle into Canada.*	OPG staff understand these requirements and will continue to comply.

General Nuclear Safety and Control Regulations		
Section	**Requirement**	**OPG Response**
Licences - General Application Requirements		
3 (1)	*An application for a licence shall contain the following information:* *(a) the applicant's name and business address;*	Applicant's name and business address: **Ontario Power Generation, Inc** **700 University Avenue,** **Toronto, Ontario, M5G 1Z5** Official Language: **English** Contact person, signing authority and licence holder: **Kapil Aggarwal** **Vice President** **Nuclear Sustainability Services,** **Ontario Power Generation** **Telephone: 416-402-6484**
	(b) the activity to be licensed and its purpose;	OPG requests an amendment to the PWMF WFOL, WFOL-W4-350.00/2028, to authorize the storage of minimum 6-year cooled fuel from Pickering NGS.
	(c) the name, maximum quantity and form of any nuclear substance to be encompassed by the licence;	100 Dry Storage Containers (DSC's) containing less than 10-year cooled used fuel from Pickering NGS. These 100 DSC's are included in the current approved total for PWMF (and are not considered <u>additional</u> to the inventory).
	(d) a description of any nuclear facility, prescribed equipment or prescribed information to be encompassed by the licence;	A description of the PWMF is provided in Attachment 2 of this submission.

General Nuclear Safety and Control Regulations		
Section	**Requirement**	**OPG Response**
	(e) the proposed measures to ensure compliance with the Radiation Protection Regulations, the Nuclear Security Regulations and the Packaging and Transport of Nuclear Substances Regulations, 2015;	OPG understands this requirement and will remain in compliance with the current licence conditions documented in WFOL-W4-350.00/2028 and with the Radiation Protection Regulations, the Nuclear Security Regulations, and the Packaging and Transport of Nuclear Substances Regulations as described in Attachment 2 of this submission.
	(f) any proposed action level for the purpose of section 6 of the Radiation Protection Regulations;	The requested WFOL amendment will not require changes to the radiation protection action levels.
	(g) the proposed measures to control access to the site of the activity to be licensed and the nuclear substance, prescribed equipment or prescribed information;	The requested WFOL amendment will not require changes to the measures to control PWMF site access, the nuclear substance, prescribed equipment or prescribed information.
	(h) the proposed measures to prevent loss or illegal use, possession or removal of the nuclear substance, prescribed equipment or prescribed information;	The requested WFOL amendment will not require changes to the measures to prevent loss or illegal use, possession or removal of the nuclear substance, prescribed equipment or prescribed information.
	(i) a description and the results of any test, analysis or calculation performed to substantiate the information included in the application;	The requested PROL amendment to authorize the storage of minimum 6-year cooled fuel at PWMF is supported by a robust safety case that is included with this submission (Enclosures 1-5) and is summarized in Attachment 2 of this submission.

	(j) the name, quantity, form, origin and volume of any radioactive waste or hazardous waste that may result from the activity to be licensed, including waste that may be stored, managed, processed or disposed of at the site of the activity to be licensed, and the proposed method for managing and disposing of that waste;	This waste will be managed in accordance with OPG's current programs and processes. No hazardous waste will be generated from the storage of minimum 6-year cooled fuel.
	(k) the applicant's organizational management structure insofar as it may bear on the applicant's compliance with the Act and the regulations made under the Act, including the internal allocation of functions, responsibilities and authority;	The organizational management structure will not change as a result of the requested licence amendment.

General Nuclear Safety and Control Regulations		
Section	**Requirement**	**OPG Response**
	(l) a description of any proposed financial guarantee relating to the activity to be licensed; and	OPG understands the regulatory requirements for a financial guarantee. The financial guarantee for PWMF will not change as a result of the requested PROL amendment.
	(m) any other information required by the Act or the regulations made under the Act for the activity to be licensed and the nuclear substance, nuclear facility, prescribed equipment or prescribed information to be encompassed by the licence.	OPG understands this requirement and will continue to comply.
(1.1)	*The Commission or a designated officer authorized under paragraph 37(2)(c) of the Act, may require any other information that is necessary to enable the Commission or the designated officer to determine whether the applicant* *(a) is qualified to carry on the activity to be licensed;* *(b) will, in carrying on that activity, make adequate provision for the protection of the environment, the health and safety of persons and the maintenance of national security and measures required to implement international obligations to which Canada has agreed.*	OPG understands this requirement and will continue to comply.
Application for Amendment, Revocation or Replacement of Licence		
6	*An application for the amendment, revocation or replacement of a licence shall contain the following information:* *(a) a description of the amendment, revocation or replacement and of the measures that will be taken and the methods and procedures that will be used to implement it;*	Attachment 2 of this submission documents the description of the amendment and of the measures that will be taken and the methods and procedures that will be used to implement it.

General Nuclear Safety and Control Regulations		
Section	**Requirement**	**OPG Response**
	(b) a statement identifying the changes in the information contained in the most recent application for the licence; *(c) a description of the nuclear substances, land, areas, buildings, structures, components, equipment and systems that will be affected by the amendment, revocation or replacement and of the manner in which they will be affected; and* *(d) the proposed starting date and the expected completion date of any modification encompassed by the application.*	Attachment 2 of this submission documents the changes that will be required to any licensing basis documents. The minimum 6-year cooled fuel will be stored within a specified array in PWMF Storage Building (SB) #3, a shielded building. The younger fuel will be stored in the same DSC's that are being used to store minimum 10-year cooled fuel. Initial loading of 2-4 DSC's containing minimum 6-year cooled fuel is proposed to commence in July 2024. After obtaining indicators related to temperature and dosage, the full campaign of storing 6-year cooled fuel will commence.
Incorporation of Material in Application		
7	*An application for a licence or for the renewal, suspension in whole or in part, amendment, revocation or replacement of a licence may incorporate by reference any information that is included in a valid, expired or revoked licence.*	OPG understands and has provided applicable references to information contained in the existing licence and Licence Conditions Handbook.
Obligations		
12 (1)	***Obligations of Licensees*** *Every licensee shall*	OPG understands the requirements and will continue to comply. Specifically:
	(*a) ensure the presence of a sufficient number of qualified workers to carry on the licensed activity safely and in accordance with the Act, the regulations made under the Act and the licence;*	The regulatory requirement will not change as a result of the requested licence amendment.

	(b) train the workers to carry on the licensed activity in accordance with the Act, the regulations made under the Act and the licence;	OPG staff will be trained on operation and maintenance activities associated with the requested licence amendment.

General Nuclear Safety and Control Regulations		
Section	**Requirement**	**OPG Response**
	(c) take all reasonable precautions to protect the environment and the health and safety of persons and to maintain the security of nuclear facilities and of nuclear substances;	Refer to section LC 9.1 in Attachment 2 of this submission for details on environmental protection. Refer to section LC 12.1 in Attachment 2 of this submission for further details on the impact to security.
	(d) provide the devices required by the Act, the regulations made under the Act and the licence and maintain them within the manufacturer's specifications;	OPG understands this requirement and will continue to comply.
	(e) require that every person at the site of the licensed activity use equipment, devices, clothing and procedures in accordance with the Act, the regulations made under the Act and the licence;	OPG understands this requirement and will continue to comply.
	(f) take all reasonable precautions to control the release of radioactive nuclear substances or hazardous substances within the site of the *licensed activity and into the environment as a result of the licensed activity;*	OPG understands this requirement and will continue to comply. Refer to section LC 9.1 in Attachment 2 for further details on security.
	(g*) implement measures for alerting the licensee to the illegal use or removal of a nuclear substance, prescribed equipment or prescribed information, or the illegal use of a nuclear facility;*	OPG understands this requirement and will continue to comply. Refer to section LC 13.1 in Attachment 2 of this submission for further details on security.
	(h) implement measures for alerting the licensee to acts of sabotage or attempted sabotage anywhere at the site of the licensed activity;	OPG understands this requirement and will continue to comply.
	(i) take all necessary measures to facilitate Canada's compliance with any applicable safeguards agreement;	OPG understands this requirement and will continue to comply. Refer to section LC 13.1 in Attachment 2 of this submission for further details on safeguards.
	(j) instruct the workers on the physical security program at the site of the licensed	OPG understands this requirement and will continue to comply.

General Nuclear Safety and Control Regulations		
Section	**Requirement**	**OPG Response**
	activity and on their obligations under that program;	Refer to section LC 12.1 in Attachment 2 of this submission for further details on security.
	(k) keep a copy of the Act and the regulations made under the Act that apply to the licensed activity readily available for consultation by the workers.	OPG understands this requirement and will continue to comply.
12 (2)	*Every licensee who receives a request from the Commission or a person who is authorized by the Commission for the purpose of this subsection, to conduct a test, analysis, inventory or inspection in respect of the licensed activity or to review or to modify a design, to modify equipment, to modify procedures or to install a new system or new equipment shall file, within the time specified in the request, a report with the Commission that contains the following information:* *(a) confirmation that the request will or will not be carried out or will be carried out in part;* *(b) any action that the licensee has taken to carry out the request or any part of it;* *(c) any reasons why the request or any part of it will not be carried out;* *(d) any proposed alternative means to achieve the objectives of the request; and* *(e) any proposed alternative period within which the licensee proposes to carry out the request.*	OPG understands this requirement and will continue to comply. Testing and commissioning procedures and reports associated with the storage of minimum 6-year cooled fuel will be made available to facilitate the regulatory role of CNSC staff.
Transfers		
13	*No licensee shall transfer a nuclear substance, prescribed equipment or prescribed information to a person who does not hold the licence, if any, that is required to possess the nuclear substance,*	OPG understands this requirement and will continue to comply.

General Nuclear Safety and Control Regulations		
Section	**Requirement**	**OPG Response**
	prescribed equipment or prescribed information by the Act and the regulations made under the Act.	
Notice of Licence		
14	*(1) Every licensee other than a licensee who is conducting field operations shall post, at the location specified in the licence or, if no location is specified in the licence, in a conspicuous place at the site of the licensed activity,* *(a) a copy of the licence, with or without the licence number, and a notice indicating the place where any record referred to in the licence may be consulted; or* *(b) a notice containing* *(i) the name of the licensee,* *(ii) a description of the licensed activity,* *(iii) a description of the nuclear substance, nuclear facility or prescribed equipment encompassed by the licence, and* *(iv) a statement of the location of the licence and any record referred to in it.* *(2) Every licensee who is conducting field operations shall keep a copy of the licence at the place where the field operations are being conducted.* *(3) Subsections (1) and (2) do not apply to a licensee in respect of* *(a) a licence to import or export a nuclear substance, prescribed equipment or prescribed information;* *(b) a licence to transport a nuclear substance; or* *(c) a licence to abandon a nuclear substance, a nuclear facility,*	OPG understands this requirement and will continue to comply with this requirement.

General Nuclear Safety and Control Regulations		
Section	**Requirement**	**OPG Response**
	prescribed equipment or prescribed information.	
Publication of Health and Safety Information		
16	*(1) Every licensee shall make available to all workers the health and safety information with respect to their workplace that has been collected by the licensee in accordance with the Act, the regulations made under the Act and the licence.* *(2) Subsection (1) does not apply in respect of personal dose records and prescribed information.*	OPG understand this requirement and will continue to comply. OPG's Health and Safety Policy is posted on the OPG intranet website.
Obligations of Workers		
17	*Every worker shall:* *(a) use equipment, devices, facilities and clothing for protecting the environment or the health and safety of persons, or for determining doses of radiation, dose rates or concentrations of radioactive nuclear substances, in a responsible and reasonable manner and in accordance with the Act, the regulations made under the Act and the licence;* *(b) comply with the measures established by the licensee to protect the environment and the health and safety of persons, maintain security, control the levels and doses of radiation, and control releases of radioactive nuclear substances and hazardous substances into the environment;* *(c) promptly inform the licensee or the worker's supervisor of any situation in which the worker believes there may be* *(i) a significant increase in the risk to the environment or the health and safety of persons,*	OPG understands this requirement and will continue to comply.

General Nuclear Safety and Control Regulations		
Section	**Requirement**	**OPG Response**
	(ii) a threat to the maintenance of the security of nuclear facilities and of nuclear substances or an incident with respect to such security, *(iii) a failure to comply with the Act, the regulations made under the Act or the licence,* *(iv) an act of sabotage, theft, loss or illegal use or possession of a nuclear substance, prescribed equipment or prescribed information, or* *(v) a release into the environment of a quantity of a radioactive nuclear substance or hazardous substance that has not been authorized by the licensee;* *(d) observe and obey all notices and warning signs posted by the licensee in accordance with the Radiation Protection Regulations; and* *(e) take all reasonable precautions to ensure the worker's own safety, the safety of the other persons at the site of the licensed activity, the protection of the environment, the protection of the public and the maintenance of the security of nuclear facilities and of nuclear substances.*	

Radiation Protection Regulations		
Section	**Requirement**	**OPG Response**
4	*Every licensee must implement a radiation protection program and must, as part of that program,* *(a) keep the effective dose and equivalent dose received by and committed to persons as low as reasonably achievable, taking into account social and economic factors, through the implementation of* *(i) management control over work practices,* *(ii) personnel qualification and training,* *(iii) control of occupational and public exposure to radiation, and* *(iv) planning for unusual situations; and* *(b) ascertain the quantity and concentration of any nuclear substance released as a result of the licensed activity* *(i) by direct measurement as a result of monitoring, or* *(ii) if the time and resources required for direct measurement as a result of monitoring outweigh the usefulness of ascertaining the quantity and concentration using that method, by estimating them.*	OPG has a well-established radiation protection program that complies with all elements of the Radiation Protection Regulations. Further details are provided in Section LC 7.1 on OPG's Radiation Protection considerations for the loading of minimum 6-year cooled fuel.

Nuclear Security Regulations
OPG will continue to adhere to all facets of the Nuclear Security Regulations and keep in place all current security processes in the handling and storage of used fuel from Pickering NGS.

ATTACHMENT #2

Licence Amendment Application for the Storage Of Minimum 6-Year Cooled Fuel at Pickering Waste Management Facility

ATTACHMENT 2

LICENCE AMENDMENT APPLICATION FOR THE STORAGE OF MINIMUM 6-YEAR COOLED FUEL AT THE PICKERING WASTE MANAGEMENT FACILITY

Prepared by: Cliff Barua

Checked by: Heather Innis

Introduction

Background

The purpose of this attachment is to provide information in support of OPG's request for amendment to the Pickering Waste Management (PWMF) Waste Facility Operating Licence (WFOL), WFOL-W4-350.00/2028, to allow for the storage of minimum 6-year cooled used fuel from Pickering Nuclear Generating Station (PNGS).

Description of PWMF – Used Fuel Dry Storage

The PWMF is located within the traditional territory of the Michi Saagiig Anishinaabe people. These lands are covered by the Williams Treaty between Canada and the Mississauga and Chippewa Nations. The PWMF operates under a Waste Facility Operating Licence (WFOL). At the PWMF, OPG processes and stores dry storage containers (DSCs) containing used nuclear fuel (high-level radioactive waste) generated at the PNGS, that has cooled for a minimum of ten years in the fuel bays at PNGS.

The dry storage of used fuel at the PWMF spans over 2 physically separate areas - Phase I and Phase II - within the overall boundary of the Pickering site. Phase I is located within the protected area of the PNGS and consists of the DSC Processing Building and two DSC storage buildings (Storage Buildings #1 and #2). Phase II of the PWMF is located northeast of Phase I and is contained within its own protected area, but within the boundary of the Pickering site. Phase II contains Storage Building #3 and #4. The PWMF currently has the capacity to store 1,778 DSCs. The transfer route of the loaded DSCs from the PWMF Phase I to the PWMF Phase II is solely on OPG property.

The information provided in this Attachment is divided into three sections as follows:

Section 1: Provides the need to store minimum 6-year cooled fuel at PWMF to support the Safe Storage Project at PNGS Units 5-8, and operational considerations for this activity.

Section 2: Summarizes regulatory compliance for the storage of younger than 10-year cooled fuel at PWMF and impact on OPG's governance, programs and processes for each of PWMF's WFOL's fourteen (14) Safety and Control Areas (SCA).

Section 3: Summarizes public, Indigenous and Metis engagement related to the application of licence amendment.

OPG is responsible for continued safe operation of the PWMF and confirms that the storage of minimum 6-year cooled fuel will be implemented based on a robust safety case and proven engineering methods.

OPG has concluded that the proposed activities to support the storage of minimum six-year cooled fuel will not compromise continued safe operation of the PWMF. OPG has and will continue to follow a robust and well-established Engineering Change Control (ECC) process and will continue to provide information to CNSC staff to assist in fulfillment of their regulatory oversight role.

The storage of minimum 6-year cooled fuel at PWMF is an important initiative to support the OPG Safe Storage Project for PNGS Units 5-8. The objective is to **only** accept minimum 6-year cooled fuel at PWMF from PNGS Units 5-8 (and **not** PNGS Units 1 and 4).

Section 1: Summary of Proposed Activity Requiring Licence Amendment

To support the OPG Safe Storage Project for PNGS, additional space in the PNGS-B Irradiated Fuel Bay (IFB-B) is required in order to accept the discharged used fuel from the required core dumps. As PWMF is currently waiting for IFB-B used fuel to mature to the 10-year required period before transferring, there is a need to accept younger fuel (as young as 6-year cooled fuel) to allow for the additional space. However, OPG is currently licensed to only process minimum 10-year cooled fuel at all Nuclear Waste Facilities. In order to store younger (i.e., fuel as young as 6-year cooled), OPG must apply for a License Amendment for the PWMF's Operating License (WFOL-W4-350.00/2028).

Master EC# 154806, "Loading, Processing and Storing a Maximum of 100 Dry Storage Containers (DSCs) (at one time) that Contain Used Fuel with a Minimum Cooling Period of 6 Years of Age in PWMF" was initiated to support the PNGS-B and PWMF operational need. The modification includes loading, transferring, processing and storage of up to 100 DSCs from the IFB-B that contain used fuel with a minimum cooling period of 6 years as well as the rearrangement of a number of the existing DSCs in Storage Building 3 (SB3) to accommodate the incoming DSCs. The younger used fuel will be loaded into DSCs in the IFB-B, transferred to the PWMF for processing, moved into the IAEA Surveillance Area in Storage Building 1 (SB1) for the application of safeguard seals and transferred for storage into SB3. Once all fuel in a DSC reaches the minimum cooling period of 10 years, the DSC can be treated the same as existing DSCs in the Used Fuel Storage Buildings at PWMF (and would not be considered part of the inventory of 100 DSC's containing younger than 10-year cooled fuel). Based on the analysis performed, it was determined that no design changes are required to the DSC to accept the storage of younger fuel within the DSC and stored in the PWMF storage buildings.

OPG proposes to start commissioning DSC's containing younger cooled fuel in July 2024, with the aim to initially gather predictive indicators around temperature and dosage. If this initial campaign proves successful (indicators are agreeable with modelling predictions) and doesn't present unforeseen challenges, the full campaign to store the younger cooled fuel would commence in Q1 of 2025.

Safety Case

Safety is OPG's number one priority, proven over many years of both reactor operation and radioactive waste management and storage. OPG is responsible for continued safe operation of the PWMF and confirms that the minimum 6-year cooled fuel modifications at PWMF will be implemented based on a robust safety case and in accordance with OPG's Engineering Change Control process, which is supported by safety assessments (Enclosures 2-3) that demonstrate continued safe facility operation, public and worker safety, and environmental protection.

The safety case for the storage of younger than 10-year cooled fuel at PWMF can be defined based on the following elements:

1) Design: OPG has and will continue to follow its Engineering Change Control process, as described in N-PROG-MP-0001, "*Engineering Change Control*", for ensuring the design complies with applicable PWMF Licence Condition Handbook, LCH-W4-350.00/2028, regulatory requirements and that configuration management for the station is maintained.

2) Continued Safe Operation: Safety analysis (Enclosure 1) demonstrates that the storage of younger than 10-year cooled fuel at PWMF will have a negligible effect on safe operation of PWMF, and on public and worker safety.

3) Environmental Protection: An assessment of existing environmental-related submissions to the CNSC (environmental assessments, environmental risk assessment and predictive environmental effects assessment) (Enclosure 6) concludes that the storage of younger than 10-year cooled fuel at PWMF will have negligible impact on the environment.

4) Licensing Basis: The storage of younger than 10-year cooled fuel at PWMF will have negligible impact on PWMF's licensing basis, governance, programs and processes. Attachment 1 documents the impact on the "*Nuclear Safety Control Act*" and applicable regulations.

Overall, there are no notable safety or operational issues that result from storing younger than 10-year cooled fuel at PWMF.

Section 2: Safety and Control Areas

The purpose of this section is to document the impact of the storage of minimum 6-year cooled fuel on OPG's (and hence PWMF's) governance, programs and processes. A review of the impact on the PWMF WFOL's fourteen (14) Safety and Control Areas (SCA's) was completed and is summarized in the following sections.

OPG is responsible for the continued safe operation of the PWMF and confirms that all modifications made with respect to the storage of younger than 10-year cooled fuel, will be implemented based on a robust safety case and in accordance with OPG's ECC process and that is supported by safety assessments, which demonstrate continued safe operation of the PWMF, public safety, worker safety and environmental protection.

LC 1.1 Management System

Licence Condition 1.1 states "*the licensee shall implement and maintain a management system*" and the details in the PWMF Licence Conditions Handbook (LCH) outline the regulatory requirements. The information provided in the last PWMF licence application is still valid.

OPG's proven Nuclear Management System provides a framework that establishes the processes and programs required to ensure OPG achieves its safety objectives, continuously monitors its performance against these objectives, and fosters a healthy safety culture.

List of Management System Related Regulatory Requirements

Licensing Basis Document Title	Document Number	Impact from the Storage of Minimum 6-Year Cooled Fuel
Management System Requirements for Nuclear Facilities	CSA N286 (2012)	Continued compliance as applied to all aspects of operation and modifications at PWMF.

Quality Assurance, CSA Standard N286-12 Compliance

PWMF is compliant with CSA Standard N286-12, "*Management system requirements for nuclear facilities*". The Nuclear Charter, N-CHAR-AS-0002, "*Nuclear Management System*", establishes the Nuclear Management System for OPG Nuclear. The Nuclear Management System will not change as a result of the proposed storage of minimum 6-year cooled fuel at PWMF.

Impact of the Storage of Minimum 6-Year Cooled Fuel on OPG Governance, Programs and Processes

The table below provides the list of OPG governance, programs and processes that form the licensing basis for PWMF's Management System and identifies the impact of storing younger than ten-year cooled fuel on these programs and processes.

Impact of the Storage of Minimum 6-year Cooled Fuel on PWMF's Management System Licensing Basis Documents

OPG Management System Licensing Basis Document Title	OPG Document Number	Impact from Storage of Minimum 6-Year Cooled Fuel
Items and Services Management	OPG-PROG-0009	No Change
Health and Safety Managed Systems	OPG-PROG-0005	No Change
Nuclear Management Systems Organization	N-STD-AS-0020	No Change
Nuclear Safety Culture Assessment	N-PROC-AS-0077	No Change
Nuclear Safety Oversight	N-STD-AS-0023	No Change
Nuclear Safety Policy	N-POL-0001	No Change
Nuclear Management System	N-CHAR-AS-0002	No Change

LCH 1.2 Management of Contractors

Licence Condition 1.2 states "*the licensee shall ensure that every contractor at the facility complies with this licence*" and the details in the PWMF Licence Conditions Handbook (LCH) outline the regulatory requirements. The information provided in the last PWMF licence application is still valid.

Vendors and contractors are qualified by OPG Supply Chain Quality Services under a process that ensures that the contractors have developed and implemented a management system that meets the applicable requirements outlined in the CSA Standard N286 series of standards. OPG is ultimately responsible for ensuring that all on-site contractor activities comply with OPG's safety requirements. Day-to-day operations at the PWMF are generally maintained by full-time staff of OPG.

LCH 2.1 Human Performance Program

Licence Condition 2.1 states "*the licensee shall implement and maintain a human performance program*" and the details in the PWMF Licence Conditions Handbook (LCH) outline the regulatory requirements. The information provided in the last PWMF licence application is still valid.

Human performance relates to reducing the likelihood of human error in work activities. It refers to the outcome of human behaviour, functions and actions in a specified environment, reflecting the ability of workers and management to meet the system's defined performance under the conditions in which the system will be employed.

List of Human Performance Management Related Regulatory Requirements

Licensing Basis Document Title	Document Number	Impact from Storage of Minimum 6-Year Cooled Fuel
Fitness for Duty: Managing Worker Fatigue	CNSC REGDOC-2.2.4 (2017)	Continued compliance, no impact.
Fitness for Duty, Volume II: Managing Alcohol and Drug Use, Version 2	CNSC REGDOC- 2.2.4 (2017)	Continued compliance, no Impact.
Safety Culture	CNSC REGDOC-2.1.2 (2018)	Continued compliance, no impact.

Human Performance Program

The objective of OPG's Human Performance program, N-PROG-AS-0002, "*Human Performance*" is to reduce human performance events and errors by managing defences in pursuit of zero events of consequence.

The Human Performance program integrates proactive (prevention) and reactive (detection and correction) human performance initiatives, which includes the following:

- Providing oversight and mentoring of department human performance.
- Identifying emerging human performance issues and determining strategies for related improvement.
- Approving site-wide human performance improvement initiatives and measures and overseeing implementation progress.
- Use of the human performance toolbox, prevent event tools.
- Identifying and implementing human performance improvement communication, education, and training opportunities.

The site strategic plan provides guidance to the leadership team on the requirements for the development and implementation of an integrated site and department human performance strategic plan. Department managers and supervisors develop a human performance plan that sets clear direction and priorities to achieve common goals.

Fitness for Duty

As part of OPG's fitness for duty program, OPG has in place a Continuous Behaviour Observation Program which trains supervisors and managers to monitor workers for signs of fatigue or other factors which could adversely impact worker performance.

OPG has in place hours of work requirements that are documented in N-PROC-OP-0047*, "Hours of Work Limits and Managing Worker Fatigue"* that sets limits for the number of hours within a specified time period that station staff can work. The limits, which are in place to guard against fatigue in the workplace, are very strict in comparison to other jurisdictions.

The storage of minimum 6-year cooled fuel will not impact OPG's fitness for duty program or compliance to hours-of-work requirements.

Impact of the Storage of Minimum 6-year Cooled Fuel on PWMF's Human Performance Program Licensing Basis Documents

The table below provides the list of OPG governance, programs and processes that form the licensing basis for PWMF's Human Performance program and identifies the impact of the storage of minimum 6-year cooled fuel on these programs and processes.

Impact of Younger than 10-year Cooled Fuel on PWMF's Human Performance Management Licensing Basis Documents

OPG Human Performance Licensing Basis Document Title	OPG Document Number	Impact from Storage of Minimum 6-Year Cooled Fuel
Human Performance	N-PROG-AS-0002	No Change
Hours of Work Limits and Managing Worker Fatigue	N-PROC-OP-0047	No Change

LC 2.2. Training Program

Licence Condition 2.2 states "*the licensee shall implement and maintain a training program*" and the details in the PWMF Licence Conditions Handbook (LCH) outline the regulatory requirements. The information provided in the last PWMF licence application is still valid.

Personnel at the PWMF will be fully trained on the loading of minimum 6-year year cooled fuel and also on mitigative measures for backout when required. All required staff will be fully trained before the first DSC containing younger than 10-year cooled fuel is commissioned.

List of Training Related Regulatory Requirements

Licensing Basis Document Title	Document Number	Impact from Storage of Minimum 6-Year Cooled Fuel
Personnel Training	CNSC REGDOC-2.2.2 (2014)	Continued compliance, no impact.

Impact of the Storage of Minimum 6-year Cooled Fuel on PWMF's Training Program Licensing Basis Documents

The table below provides the list of OPG governance, programs and processes that form the licensing basis for PWMF's Training program and identifies the impact of the storage of minimum 6-year cooled fuel on these programs and processes.

Impact of Minimum 6-year Cooled Fuel on PWMF's Training Program Licensing Basis Documents

OPG Human Performance Licensing Basis Document Title	OPG Document Number	Impact from Storage of Minimum 6-Year Cooled Fuel
Systematic Approach to Training	N-PROC-TR-0008	No Change
Training	N-PROG-TR-0005	No Change

LC 3.1 Operating Performance

Licence Condition 3.1 states "*the licensee shall implement and maintain an operating program, which includes a set of operating limits*" and the details in the PWMF Licence Conditions Handbook (LCH) outline the regulatory requirements. The information provided in the last PWMF licence application is still valid.

Operational Analysis

Processing minimum 6-year cooled fuel is essentially the same as processing 10-year cooled fuel. There will be minor changes required to operational documentation and procedures. DSCs that contain as young as 6-year cooled fuel have been analyzed for the anticipated temperatures throughout the DSC. Based on conservative bounding scenario assumptions, it has been conservatively identified that contact temperatures could potentially reach approximately 85 degrees Celsius (°C), which impacts worker safety in handling the DSC. The increased temperatures potentially impact interfacing equipment such as Advanced Inspection and Maintenance (AIM) equipment and International Atomic Energy Agency (IAEA) equipment including seals and NDE profiling.

Based on OPEX from 1998, DSC 0024 contained four full modules (384 bundles) of 6-year cooled fuel and had temperature probes fixed to the DSC. Temperature measurements were much lower than the conservative design analysis from 2022. These temperatures are documented in OPG Controlled Document 00104-CORR-79171-0139942 "Additional Information Concerning: Thermal Gradients Pertaining to Dry Storage Containers (DSCs)" (2005) and summarized in Figure 1 below. Based on this OPEX, it is anticipated that contact temperatures will not be as high as analyzed.

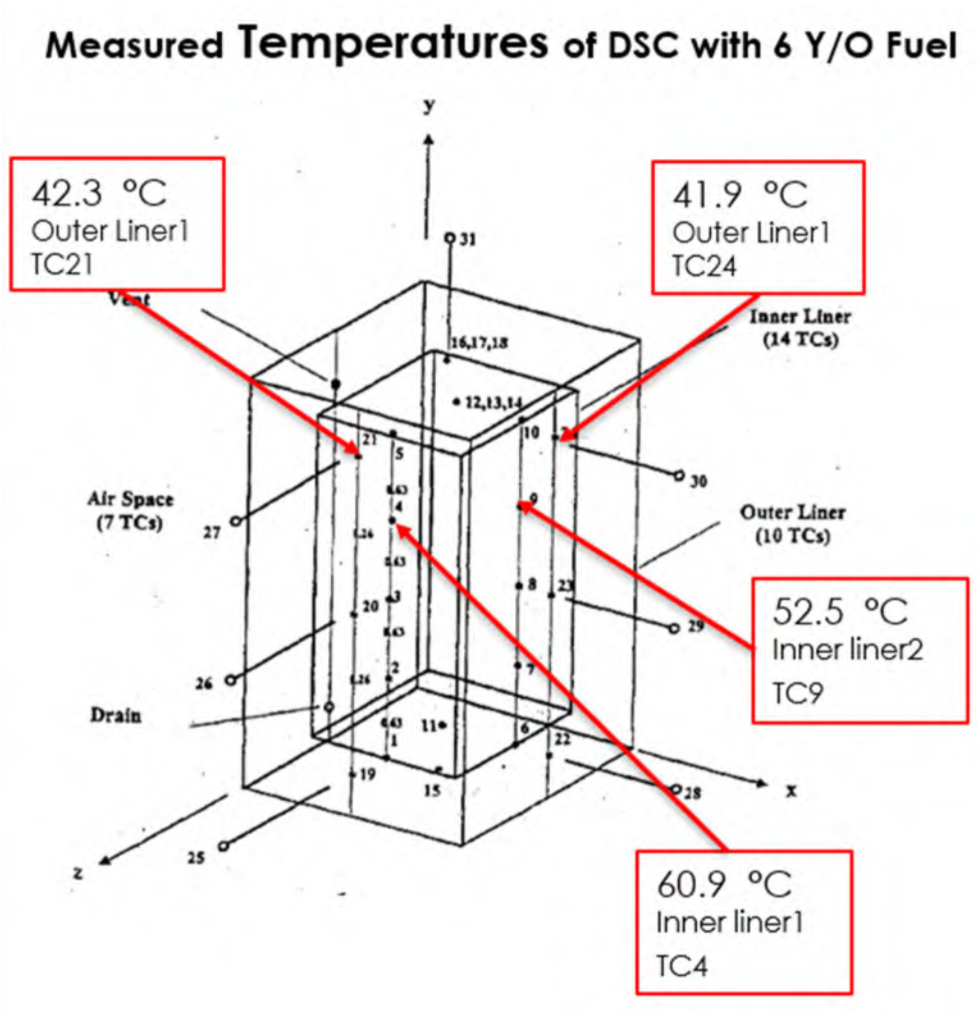

Figure 1: Measured Temperatures in DSC 0024

Commissioning Plan

Operationally, only one DSC is required to be loaded with 6-year cooled fuel to commission the modification. However, to avoid reverse loading (see Reverse Loading below), a conservative approach is recommended to be used. A potential option would be to load and vacuum dry the commissioning DSCs, starting with 9-year cooled fuel and working down to 6-year cooled fuel while measuring temperatures and dose rates. Based on OPG report with Controlled Document I-REP-79171-00001, the time taken for the outer liner of the DSC to reach equilibrium temperature is of the order of three weeks on average. Therefore, this option will take several months to complete the commissioning.

Acceptable temperatures are driven by Advance Inspection and Maintenance (AIM) and IAEA equipment at specific DSC locations outlined in Table 1 below:

Table 1 - IAEA/AIM Equipment Temperature Limits

Container Location	Equipment	Temp. Limit	Analyzed Temp.	OPEX Temp. DSC 0024
Weld Flange	AIM – Phased Array Ultrasonic Testing – (PAUT)	50 °C	~ 85 °C	~ 45 °C
Weld Flange	IAEA - Laser Container Mapping Verification	Deformation ~60 °C (Estimate)	~ 85 °C	~ 45 °C
Seal Tubes	IAEA -Fiber Optic Seals	Degradation ~70 °C (Estimate)	~100 °C	< 62 °C

IAEA temperature limits in Table 1 are estimates since they are not allowed to be identified. Estimates listed in Table 1 are based on discussions with IAEA.

AIM Equipment

As part of the commissioning, the intent is to ensure that the temperatures meet AIM equipment requirements before proceeding with the welding and continuation of processing the DSC to interim storage. The AIM equipment has a temperature limitation 50°C, shown in Table 1 above. If temperatures are measured less than 50°C, then nothing changes except conventional and Radiation Protection (RP) safety aspects. The AIM Acquisition Procedure would remain unaltered and there would be no issue.

Options have been considered for cooling the DSC flange if temperatures are measured in excess 50°C. Details on flange cooling are discussed below. If temperatures exceed 50°C, and the flange cooling methods are ineffective then the DSC will be Reverse loaded (discussed below).

Flange cooling: options for cooling the DSC flange are available if temperatures are measured in excess 50°C. Having an effective means to cool the DSC temperatures reduces the risk of having to resort to the back-out option (Reverse Loading).

IAEA Equipment

Temperature limits for IAEA are listed in Table 1 above. The impact of higher temperatures on IAEA safeguards and security interfacing equipment is being evaluated and discussion with the IAEA and CNSC is in progress. There is a risk that some IAEA equipment used for the sealing processes is not designed for the increased temperatures that could be observed.

Current proposal to the IAEA is to:

- Load and Vacuum Dry commissioning DSC with 6-year old fuel.
- Within Camera View – Allow DSC to reach maximum temperature (not welded).
- Allow for residency time of three weeks to allow for DSC to reach equilibrium temperature, measure temperatures and doses.

- If temperatures are conducive for Fiber Optic seals: complete DSC processing. Confirm weld flange temperatures before sealing with IAEA.
- If temperatures exceed limits outlined in Table 1 above, OPG suggest tri-seals to be applied (i.e., LMCV, FBOS, & Metallic). Monitor health seals during regular IAEA visits. OPG will also explore using mixed age modules.
- If the above commissioning DSC is excessively hot, then the DSC will need to be reverse loaded (see below, Reverse Loading). DSC temperatures will be controlled operationally – for example through the mixed age module loading.

Based on discussions, the IAEA have agreed to support the commissioning DSC test case to see if the actual temperatures are similar to the calculated temperatures or more similar to OPEX of DSC 0024. An Operating Memo is currently being prepared to provide the changes to documents required to operationalize the change. This will be completed prior to commissioning of the first DSC.

<u>Reverse Loading</u>

If the temperatures are higher than the limits required as discussed above, there will need to be a backout option to reverse load the DSC back to the IFB-B. A reverse loading plan is being developed to outline the steps required to reverse load a DSC loaded with 6-year cooled fuel. This is being developed using OPEX from 2012 to address an issue with a partially loaded DSC 1538. This DSC had to be emptied (SCR N-2012-00289). The reverse loading plan will be issued before the loading of any DSC's containing minimum 6-year cooled fuel.

<u>Impact of the Storage of Minimum 6-Year Cooled Fuel on OPG Governance, Programs and Processes</u>

The table below provides the list of OPG governance, programs and processes that form the licensing basis for PWMF's Operating Performance and identifies the impact of the storage of minimum 6-year cooled fuel on these programs. Identified changes in new revisions of licensing basis documents will be submitted by written notification to the CNSC per the requirements of the PWMF LCH LC G2.

<u>Impact of the Storage of Minimum 6-Year Cooled Fuel on PWMF's Operating Performance Related Licensing Basis Documents</u>

OPG Document Title	OPG Document Number	Impact from the Storage of Minimum 6-Year Cooled Fuel
Application for Renewal of Pickering Waste Management Facility Operating Licence	92896-CORR-00531-01031	No Change
Additional Information to Support the Application for Renewal of Pickering	92896-CORR-00531-01075	No Change

Waste Management Facility Operating Licence		
Nuclear Waste Management	W-PROG-WM-0001	No Change
Operating Policies and Principles, Pickering Waste Management Facility	92896-OPP-01911.1-00001	To be updated by March 15, 2024.
Pickering Waste Management Facility – Safety Report	92896-SR-01320-10002	Changes will be reflected in the next update of the PWMF Safety Report scheduled for 2028.

Impact of the Storage of Minimum 6-Year Cooled Fuel on OPG Governance, Programs and Processes

The table below provides the list of OPG governance, programs and processes that form the licensing basis for PWMF's Operating Performance and identifies the impact of the storage of younger than 10-year cooled fuel on these programs.

Impact of the Storage of Minimum 6-Year Cooled Fuel on PWMF's Operating Performance Related Licensing Basis Documents

OPG Document Title	OPG Document Number	Impact from the Storage of Minimum 6-Year Cooled Fuel
Conduct of Regulatory Affairs	N-PROG-RA-0002	No Change
Performance Improvement	N-PROG-RA-0003	No Change
Preliminary Event Notification	N-PROC-RA-0020	No Change
Operating Policies and Principles, Pickering Waste Management Facility	92896-OPP-01911.1-00001	To be updated prior to commissioning of the first DSC with younger fuel.

The following documents related to operations (but not included in the licensing basis) will also be updated prior to the commissioning of the first DSC containing minimum 6-year cooled fuel:

Document Number	Document Title
92896-MAN-79171-00001	IFB Loading
W-WOEP-79171-000010	Dry Storage Container Reverse Loading
W-PROC-WM-0082	Eastern Waste Acceptance Criteria for Used Fuel Dry Storage Containers
92896-OP-35540-00001	Pickering Waste Management Facility (PWMF) General
92896-OP-79171-00001	Pickering Waste Management Facility Operating Procedure Dry Storage Container Processing
92896-SR-01320-10002	Pickering Waste Management Facility – Safety Report
92896-OP-35570-00001	International Atomic Energy Agency Safeguards (*If required based on commissioning results)
92896-OP-79171-00003	DSC Loading PNGS 058 Irradiated Fuel Bay (IFB-B)
92896-OP-79171-00004	DSC Loading Auxiliary Irradiated Fuel Bay

LC 3.2 Reporting Requirements

Licence Condition 3.2 states "*the licensee shall implement and maintain a program for reporting to the Commission or a person authorized by the Commission*" and the details in the PWMF Licence Conditions Handbook (LCH) outline the regulatory requirements. The information provided in the last PWMF licence application is still valid.

List of Reporting Related Regulatory Requirements

Licensing Basis Document Title	Document Number	Impact from Storage of Minimum 6-Year Cooled Fuel
Public Information and Disclosure	CNSC REGDOC-3.2.1 (2018)	Continued compliance, no impact.
Reporting Requirements, Volume I: Non-Power Reactor Class I Nuclear Facilities and Uranium Mines and Mills	CNSC REGDOC-3.1.2 (2018)	Continued compliance, no impact.

Operational Quarterly and Annual Reporting

Quarterly and Annual operational reporting will continue as currently conducted and will account for the DSC's containing minimum 6-year cooled fuel.

LC 4.1 Safety Analysis Program

Licence Condition 4.1 states "*the licensee shall implement and maintain a safety analysis program*" and the details in the PWMF Licence Conditions Handbook (LCH) outline the regulatory requirements. The information provided in the last PWMF licence application is still valid.

Safety Assessment

As concluded in the safety analysis provided in Enclosure 2 to this submission: the safety assessment demonstrates compliance with the radiation safety requirements during normal operation of the PWMF when SB3 is in service. With the addition of the 100 DSCs containing 6-year decayed used fuel, the annual public dose estimates have increased compared to that of the existing PWMF configuration. The maximum annual dose to individual member of the public with the addition of these 100 DSCs is still a small percentage of the 1 mSv limit. Due to the specialised array of storing the DSC's containing minimum 6-year cooled fuel, the target dose rate to the public of 0.5mSv will also be met. With respect to malfunction and accident scenarios, the estimated bounding doses to members of the public are less than the 1 mSv acceptance criterion. The dose to workers following a postulated accident scenario is found to be much less than the 50 mSv limit. It is concluded that the dose consequences to workers and members of the public as a result of credible postulated malfunction / accident scenarios meet all acceptance criteria.

Enclosures 2 and 3 were previously provided to CNSC staff in 2020 and 2021 before it was determined that a Licence Amendment would be required to store minimum 6-year cooled fuel. Enclosure 4 contains information (previously requested by the CNSC) regarding the trialing of a single DSC containing 6-year cooled fuel in 1998.

List of Safety Analysis Program Related Regulatory Requirements

Licensing Basis Document Title	Document Number	Impact from the Storage of Minimum 6-Year Cooled Fuel
General principles for the management of radioactive waste and irradiated fuel	CSA N292.0 (2014)	Minimum 6-year cooled fuel safety assessments were

		conducted in compliance with applicable requirements
Interim dry storage of irradiated fuel	CSA N292.2 (2013)	Minimum 6-year cooled fuel safety assessments were conducted in compliance with applicable requirements
Management of low- and intermediate-level radioactive waste	CSA N292.3 (2014)	Minimum 6-year cooled fuel safety assessments were conducted in compliance with applicable requirements
Quality assurance of analytical, scientific, and design computer programs	CSA N286.7 (2016)	Minimum 6-year cooled fuel safety assessments were conducted in compliance with applicable requirements

Impact of the Storage of Minimum 6-Year Cooled Fuel on OPG Governance, Programs and Processes

The table below provides the list of OPG governance, programs and processes that form the licensing basis for PWMF's Safety Analysis program and identifies the impact of storing minimum 6-year cooled fuel on these programs and processes.

Impact of the Storage of Minimum 6-year Cooled Fuel on PWMF's Safety Analysis Licensing Basis Documents

OPG Safety Analysis Licensing Basis Document Title	OPG Document Number	Impact from the Storage of Minimum 6-Year Cooled Fuel
Pickering Waste Management Facility – Safety Report	92896-SR-01320-10002	Changes will be reflected in the next update of the PWMF Safety Report scheduled for 2028.

LC 5.1 Design Program

Licence Condition 5.1 states "*the licensee shall implement and maintain a design program*" and the details in the PWMF Licence Conditions Handbook (LCH) outline the regulatory requirements. The information provided in the last PWMF licence application is still valid.

List of Design Program Related Regulatory Requirements

Licensing Basis Document Title	Document Number	Impact from the Storage of Minimum 6-Year Cooled Fuel
Fire protection for facilities that process, handle, or store nuclear substances	CSA N393 (2013)	This code is not impacted by the storage of younger than 10-year cooled fuel.
National Building Code of Canada (2020)	NRC	The PWMF SB's design complies with the requirements in this national code.
National Fire Code of Canada (2020)	NRC	The PWMF SB's design complies with the requirements in this national code.

Facility and DSC Design

The storage of minimum 6-year cooled fuel will not require any change to the facility design. The DSC currently used for minimum 10-year cooled fuel will also be used for the storage of minimum 6-year cooled fuel.

Impact of the Storage of Minimum 6-year Cooled Fuel on OPG Governance, Programs and Processes

The table below provides the list of OPG governance, programs and processes that form the licensing basis for PWMF's Design Program and identifies the impact of the storage of minimum 6-year cooled fuel on these programs and processes.

Impact of the Storage of Minimum 6-year Cooled Fuel on PWMF's Design Program Related Licensing Basis Documents

OPG Physical Design Licensing Basis Document Title	OPG Document Number	Impact from Storage of Minimum 6-Year Cooled Fuel
Conduct of Engineering	N-STD-MP-0028	No Change
Configuration Management	N-STD-MP-0027	No Change
Design Management	N-PROG-MP-0009	No Change
Engineering Change Control	N-PROG-MP-0001	No Change

LC 5.2 Pressure Boundary

Licence Condition 2.2 states "*the licensee shall implement and maintain a training program*" and the details in the PWMF Licence Conditions Handbook (LCH) outline the regulatory requirements. The information provided in the last PWMF licence application is still valid.

List of Pressure Boundary Program Related Regulatory Requirements

Licensing Basis Document Title	Document Number	Impact from the Storage of Minimum 6-Year Cooled Fuel
Power Piping	ASME (2010)	This code is not impacted by the storage of minimum 6-year cooled fuel.
Boiler, pressure vessel, and pressure piping code	CSA B51 (2009 and Update No. 1)	This code is not impacted by the storage of minimum 6-year cooled fuel.
General requirements for pressure-retaining systems and components in CANDU nuclear power plants	CSA N285.0 (2012 and Updates No. 1 and 2; and Annex N of N285.0-12 and Update No. 1)	This code is not impacted by the storage of minimum 6-year cooled fuel.

Impact of the Storage of Minimum 6-year Cooled Fuel on OPG Governance, Programs and Processes

The table below provides the list of OPG governance, programs and processes that form the licensing basis for PWMF's Design Program and identifies the impact of the storage of minimum 6-year cooled fuel on these programs and processes.

Impact of the Storage of Minimum 6-Year Cooled Fuel on PWMF's Design Program Related Licensing Basis Documents

OPG Physical Design Licensing Basis Document Title	OPG Document Number	Impact from Storage of Minimum 6-Year Cooled Fuel
Index to OPG Pressure Boundary Program Elements	N-LIST-00531-10003	No Change
Pressure Boundary Program Manual	N-MAN-01913.11-10000	No Change
Authorized Inspection Agency Service Agreement	N-CORR-00531-20012	No Change
Design Registration	N-PROC-MP-0082	No Change
Pressure Boundary	N-PROC-MP-0004	No Change
System and Item Classification	N-PROC-MP-0040	No Change

LC 6.1 Fitness for Service Program

Licence Condition 6.1 states "*the licensee shall implement and maintain a fitness for service program*" and the details in the PWMF Licence Conditions Handbook (LCH) outline the regulatory requirements. The information provided in the last PWMF licence application is still valid.

List of Fitness for Service Program Related Regulatory Requirements

Licensing Basis Document Title	Document Number	Impact from Storage of Minimum 6-Year Cooled Fuel
Aging Management	CNSC REGDOC-2.6.3 (2014)	The storage of minimum 6-year fuel will be incorporated into the aging management program as applicable as part of the ECC process.

Impact of the Storage of Minimum 6-Year Fuel on OPG Governance, Programs and Processes

The table below provides the list of OPG governance, programs and processes that form the licensing basis for PWMF's Fitness for Service and identifies the impact of the storage of minimum 6-year cooled fuel on these programs and processes.

Impact of the Storage of Minimum 6-Year Cooled Fuel on PWMF's Aging Management Program Related Licensing Basis Documents

OPG Fitness for Service Licensing Basis Document Title	OPG Document Number	Impact from Storage of Minimum 6-Year Cooled Fuel
Conduct of Engineering	N-STD-MP-0028	No Change
Design Management	N-PROG-MP-0009	No Change
Equipment Reliability	N-PROG-MA-0026	No Change
Integrated Aging Management	N-PROG-MP-0008	No Change
Nuclear Waste Management	W-PROG-WM-0001	No Change

Ontario Power Generation Dry Storage Container – Base (Underside) Inspection Plan	00104-PLAN-79171-00002	No Change
Used Fuel Dry Storage Container Aging Management Plan	00104-PLAN-79171-00001	No Change

LC 7.1 Radiation Protection

Licence Condition 7.1 states "*the licensee shall implement and maintain a radiation program, which includes a set of action levels. When the licensee becomes aware that an action level has been reached, the licensee shall notify the Commission within seven days"* and the details in the PWMF Licence Conditions Handbook (LCH) outline the regulatory requirements. The information provided in the last PWMF licence application is still valid.

As per OPG's N-PROG-RA-0013, "*Radiation Protection*", the overriding objective of the Radiation Protection (RP) program at OPG is the control of occupational and public exposure to radiation. For the purposes of controlling radiation doses to workers and the public, this program has five implementing objectives:

- Keeping individual radiation doses below regulatory limits
- Avoiding unplanned radiation exposures
- Keeping individual risk from lifetime radiation exposure to an acceptable level
- Keeping collective radiation doses ALARA, social and economic factors taken into account
- Keeping public exposure to radiation well within regulatory limits.

Higher Dose Rates

Higher dose rates from the minimum 6-year cooled fuel DSCs directly impacts workers and equipment that interface with the DSC. It has been analyzed that the anticipated dose rates would be approximately 2.5 times higher in comparison to the storage of 10-year cooled fuel. This is manageable with a different Radiation Exposure Permit (REP) to address worker safety; and no meaningful impact on OPG equipment. Dose rates will be managed with the As Low as Reasonably Achievable (ALARA) principles associated with an updated REP.

New REP's for workers interfacing with the younger cooled fuel will be developed and implemented prior to commissioning of any DSC's containing younger cooled fuel.

Estimated Public Dose

Estimated public doses have been analyzed in Enclosure 2 (section 5.3.3) and in Enclosure 3 (section 4.3.2). Both analyses assess that the dose to public, as a result of the storage of minimum 6-year cooled fuel in SB3, remains far below regulatory limits.

Based on previous correspondence with the CNSC, and reaffirmed in this application, dose rates will be measured during the initial placement of 6-year-old fuel and actions will be taken are taken prior to the dose rate criterion being exceeded.

Dose Rates and Temperature Impact on the Public and Environment

Analysis has been conducted on the indirect impact that dose rates and temperatures would have on OPG equipment and the public/environment. The transfer of the DSC from IFB-B to the processing building, then to interim storage in SB1 and lastly to its final destination in SB3. This increase in dose and temperature has been analyzed to be within the regulatory limits for the public and environment (including all Action Levels stated in the PWMF LCH).

The existing TLDs around PWMF Phase I and Phase II will measure the dose rates, which are reported quarterly to the CNSC in the facility Operations Report. Monitoring of these results will confirm the impact on the regulatory dose rates. However, as SB3 is a shielded building, it is not anticipated to be a concern.

Thermal Analysis for PWMF SB3 storing 6-year cooled fuel has been completed during design. DSC's containing 6-year cooled fuel will be placed in the middle of SB3. An increase in dose and temperature has been analyzed to be within the regulatory limits to the public and environment. Temperature monitoring inside SB3 will be in place prior to the commissioning of any DSC's containing minimum 6-year cooled fuel.

List of Radiation Protection Related Regulatory Requirements

Licensing Basis Document Title	Document Number	Impact from the Storage of Minimum 6-year Cooled Fuel
Radiation Protection Regulations	SOR/2000-203	Continued compliance as documented in Attachment 1

Impact of the Storage of Minimum 6-Year Cooled Fuel on PWMF's Radiation Protection Program Related Licensing Basis Documents

The table below provides the list of OPG governance, programs and processes that form the licensing basis for PWMF's Radiation Protection and identifies the impact of the storge of minimum 6-year cooled fuel on these programs.

Impact from the Storage of Minimum 6-year Cooled Fuel on PWMF's Radiation Protection and ALARA Licensing Basis Documents

OPG Radiation Protection Licensing Basis Document Title	OPG Document Number	Impact from the Storage of Minimum 6-year Cooled Fuel
Occupational Radiation Protection Action Levels for Nuclear Waste Management Facilities	N-REP-03420-10011	No Change
Radiation Protection	N-PROG-RA-0013	No Change

LC 8.1 Conventional Health and Safety

Licence Condition 8.1 states "*the licensee shall implement and maintain a conventional health and safety program"* and the details in the PWMF Licence Conditions Handbook (LCH) outline the regulatory requirements. The information provided in the last PWMF licence application is still valid.

Regulatory Requirements Related to Conventional Health and Safety

Licensing Basis Document Title	Document Number	Impact from the Storage of Minimum 6-year Cooled Fuel
General Nuclear Safety and Control Regulations	SOR/2000-202	Continued compliance as documented in Attachment 1

Ensuring Conventional Safety Performance

The foundation of OPG's Health and Safety Management System is OPG-POL-0001, "*Employee Health and Safety Policy*" which describes the approach and commitments to conventional health and safety for the organization, and the requirements and accountabilities of all employees.

OPG's program document OPG-PROG-0005, "*Environment Health and Safety Managed Systems*" governs the design and execution of OPG's Health and Safety Managed Systems in accordance with OPG-POL-0001. The Health and Safety Managed System program and supporting governing documents establish process requirements that protect employees by ensuring they are working safely in a healthy and injury-free workplace. It also outlines the responsibilities of various levels in the organization to ensure activities are performed to meet the requirements of OPG's Health and Safety Policy.

Impact from the Storage of Minimum 6-year Cooled Fuel on OPG Governance, Programs and Processes

The table below provides the list of OPG governance, programs and processes that form the licensing basis for PWMF's Conventional Safety program and identifies the impact of the storage of minimum 6-year cooled fuel on these programs and processes.

Impact from the Storage of Minimum 6-year Cooled Fuel on PWMF's Conventional Safety Program Licensing Basis Documents

OPG Conventional Safety Licensing Basis Document Title	OPG Document Number	Impact from the Storage of Minimum 6-year Cooled Fuel
Employee Health and Safety Policy	OPG-POL-0001	No Change
Health and Safety Management System Program	OPG-PROG-0010	No Change

LC 9.1 Environmental Protection

Licence Condition 9.1 states "*the licensee shall implement and maintain an environmental protection program, which includes a set of action levels. When the licensee becomes aware that an action level has been reached, the licensee shall notify the Commission within seven days"* and the details in the PWMF Licence Conditions Handbook (LCH) outline the regulatory requirements. The information provided in the last PWMF licence application is still valid.

List of Environmental Protection Related Regulatory Requirements

Licensing Basis Document Title	Document Number	Impact from the Storage of Minimum 6-year Cooled Fuel
Environmental Protection: Environmental Principles, Assessments and Protection Measures	REGDOC-2.9.1, Section 4.6 (2017)	Environmental-related assessments were conducted in accordance with requirements
Guidelines for calculating derived release limits for radioactive material in airborne and liquid effluents for normal operation of nuclear facilities	CSA N288.1 (2014)	Environmental-related assessments were conducted in accordance with requirements

Performance Testing of Nuclear Air-Cleaning Systems at Nuclear Facilities	CSA N288.3.4 (2013)	Environmental-related assessments were conducted in accordance with requirements
Environmental monitoring program at class I nuclear facilities and uranium mines and mills	CSA N288.4 (2015)	Environmental-related assessments were conducted in accordance with requirements
Effluent monitoring programs at class I nuclear facilities and uranium mines and mills	CSA N288.5 (2011)	Environmental-related assessments were conducted in accordance with requirements
Environmental risk assessments at class I nuclear facilities and uranium mines and mills	CSA N288.6 (2012)	Environmental-related assessments were conducted in accordance with requirements
Groundwater protection programs at Class I nuclear facilities and uranium mines and mills.	CSA N288.7 (2015)	Environmental-related assessments were conducted in accordance with requirements

Effluent and Emissions Control (Releases)

OPG is committed to complying with the requirements of the CSA Standard N288 series documents, as required in the PWMF LCH. The licensee shall control radiological releases to ALARA, thereby minimizing dose to the public resulting from PWMF operation.

The PWMF reports against approved Derived Release Limits (DRLs), which are defined in CSA Standard N288.1 as the release rate that would cause an individual of the most highly exposed group to receive and be committed to a dose equal to the regulatory annual dose limit, due to release of a given radionuclide to air or surface water during normal operation of a nuclear facility over the period of a calendar year.

Because radiological releases are very small in comparison with the Derived Release Limits (DRLs) and Action Levels, lower Internal Investigation Levels (IILs) are used to demonstrate and maintain adherence to the ALARA principle. There will be no changes to the DRLs, Action Levels or IILs as a result of the storage of younger than 10-year cooled fuel. Consistent with current performance, the cumulative public dose resulting from the storage of the younger cooled fuel will remain well below 1% of the regulatory public dose limit of 1,000 μSv per year.

Environmental Management System (EMS)

OPG's OPG-POL-0021, "*Environmental Policy*" requires that OPG maintain an Environmental Management System (EMS) consistent with the ISO 14001, "*Environmental Management System Standard*".

Operation of the PWMF will continue to be in accordance with OPG's EMS as described in OPG-PROG-0005, "*Environment Health and Safety Managed Systems*" and OPG-POL-0021. The EMS provides specific direction on how the Environmental Policy is implemented while meeting the expectations of OPG-POL-0032, "*Safe Operations Policy*", N-POL-0001, "*Nuclear Safety & Security Policy*", and N-CHAR-AS-0002, "*Nuclear Management System*".

Continued Validity of Prior Submissions to the CNSC/Licensing Documents

Enclosure 1 contains an assessment that reviewed the following current licensing documents:

Environmental Assessments (EAs):

- Pickering Waste Management Facility Phase II Final Environmental Assessment Study Report. December 2003. 92896-REP-07701-00002
- Refurbishment and Continued Operation of Pickering B Nuclear Generating Station Environmental Assessment. December 2007. NK30-REP-07701-00002

Environmental Risk Assessment (ERA) and Predictive Effects Assessment (PEA):

- ERA for Pickering Nuclear. Feb 2018. P-REP-07701-00001 R001
- PEA for Pickering Nuclear Safe Storage. April 2017. P-REP-07701-00002 R000

Operating Licences and Handbooks:

- Nuclear Power Reactor Operating Licence. Pickering Nuclear Generating Station. PROL 48.00/2028.
- Pickering Nuclear Generating Station Nuclear Power Reactor. Licence Conditions Handbook. LCH-PR-48.00/2028-R000.
- Waste Facility Operating Licence. Pickering Waste Management Facility. WFOL-W4-350.0/2028.
- Pickering Waste Management Facility. Licence Conditions Handbook. LCH-W4-350.00/2028.

As a result, OPG concluded that a stand-alone environmental submission to CNSC is not required since loading, transporting, and storage of cooled used fuel, 6-year or older, is considered to be within the scope of the relevant project EAs and falls within the conditions of the Pickering Nuclear and PWMF Waste Operating Licences.

Impact from the Storage of Minimum 6-year Cooled Fuel on OPG Governance, Programs and Processes

The table below provides the list of OPG governance, programs and processes that form the licensing basis for PWMF's Environmental Protection and identifies the impact of the storage of minimum 6-year cooled fuel on these programs and processes.

Impact from the Storage of Minimum 6-year Cooled Fuel on PWMF's Environmental Protection Licensing Basis Documents

OPG Environmental Protection Licensing Basis Document Title	OPG Document Number	Impact from the Storage of Minimum 6-year Cooled Fuel
Environment Health and Safety Managed Systems	OPG-PROG-0005	No Change
Environment Policy	OPG-POL-0021	No Change
Management of the Environmental Monitoring Program	N-PROC-OP-0025	No Change
Monitoring of Nuclear and Hazardous Substances in Effluents	N-STD-OP-0031	No Change
Environmental Risk Assessment Report for Pickering Nuclear	P-REP-07701-00001	No Change
Derived Release Limits and Environmental Action Levels for Pickering Nuclear	P-REP-03482-00006	No Change

LC 9.2 Environmental Assessment Follow-Up Program

Licence Condition 9.2 states "*the licensee shall implement an environmental assessment follow-up plan"* and the details in the PWMF Licence Conditions Handbook (LCH) outline the regulatory requirements. The information provided in the last PWMF licence application is still valid.

Enclosure 1 contains an assessment of the continued validity of the PWMF Phase II Site Environmental Assessment (EA) (December 2003) with the storage of minimum 6-year cooled fuel. As a result, the EA Follow-Up Plan also remains valid and will continue to be conducted as originally committed for SB3.

Impact from the Storage of Minimum 6-year Cooled Fuel on OPG Governance, Programs and Processes

The table below provides the list of OPG governance, programs and processes that form the licensing basis for PWMF's Environmental Assessment Follow-Up Plan and identifies the impact of the storage of minimum 6-year cooled fuel on these programs and processes.

Impact from the Storage of Minimum 6-year Cooled Fuel on PWMF's Environmental Assessment Follow-Up Plan Licensing Basis Documents

OPG Environmental Protection Licensing Basis Document Title	OPG Document Number	Impact from the Storage of Minimum 6-year Cooled Fuel
Pickering Waste Management Facility Phase II – Environmental Assessment Follow-Up Plan	92896-REP-07701.8-00001	No Change

LC 10.1 Emergency Preparedness Program

Licence Condition 10.1 states "*the licensee shall implement an emergency preparedness program"* and the details in the PWMF Licence Conditions Handbook (LCH) outline the regulatory requirements. The information provided in the last PWMF licence application is still valid.

List of Emergency Management Related Regulatory Requirements

Licensing Basis Document Title	Document Number	Impact from the Storage of Minimum 6-year Cooled Fuel
Nuclear Emergency Preparedness and Response, Version 2	CNSC REGDOC-2.10.1 (2017)	No change

Nuclear Emergency Preparedness and Response

OPG's Emergency Preparedness program N-PROG-RA-0001, "*Consolidated Nuclear Emergency Plan*", requires OPG staff to implement and maintain its emergency response capability to protect the public, employees, and the environment in the event of a nuclear emergency."

Impact of the Storage of Minimum 6-Year Fuel on OPG Governance, Programs and Processes

The table below provides the list of OPG governance, programs and processes that form the licensing basis for PWMF's Emergency Management and identifies the impact of the storage of minimum 6-year cooled fuel on these programs and processes.

Impact from the Storage of Minimum 6-year Cooled Fuel on PWMF's Emergency Management Licensing Basis Documents

OPG Emergency Management and Fire Protection Licensing Basis Document Title	OPG Document Number	Impact
Radioactive Materials Transportation Emergency Response Plan	N-STD-RA-0036	No Change
Consolidated Nuclear Emergency Plan	N-PROG-RA-0001	No Change

LC 10.2 Fire Protection Program

Licence Condition 10.2 states "*the licensee shall implement a fire protection program"* and the details in the PWMF Licence Conditions Handbook (LCH) outline the regulatory requirements. The information provided in the last PWMF licence application is still valid.

List of Fire Protection Related Regulatory Requirements

Licensing Basis Document Title	Document Number	Impact from the Storage of Minimum 6-year Cooled Fuel
Fire protection for facilities that process, handle, or store nuclear substances	CSA N393-13 (2013)	No change
National Building Code of Canada (2020)	NRC	No Change
National Fire Code of Canada (2020)	NRC	No Change

Fire Emergency Preparedness and Response

OPG's Fire Protection program, N-PROG-RA-0012, "*Fire Protection"* establishes provisions to prevent, mitigate and respond to fires such that fire risk to OPG Nuclear workers, public, environment, nuclear physical assets, and power generation, is acceptably low and controlled. There will be no changes to N-PROG-RA-0012 as a result of the storage of minimum 6-year cooled fuel.

Impact of the Storage of Minimum 6-Year Fuel on OPG Governance, Programs and Processes

The table below provides the list of OPG governance, programs and processes that form the licensing basis for PWMF's Fire Protection and identifies the impact of the storage of minimum 6-year cooled fuel on these programs and processes.

Impact from the Storage of Minimum 6-year Cooled Fuel on PWMF's Fire Protection Licensing Basis Documents

OPG Emergency Management and Fire Protection Licensing Basis Document Title	OPG Document Number	Impact from the Storage of Minimum 6-year Cooled Fuel
Fire Protection	N-PROG-RA-0012	No Change

LC 11.1 Waste Management Program

Licence Condition 11.1 states "*the licensee shall implement a waste management program"* and the details in the PWMF Licence Conditions Handbook (LCH) outline the regulatory requirements. The information provided in the last PWMF licence application is still valid.

List of Waste Management Related Regulatory Requirements

Licensing Basis Document Title	Document Number	Impact from the Storage of Minimum 6-year Cooled Fuel
General principles for the management of radioactive waste and irradiated fuel	CSA N292.0 (2019)	The storage of younger than 10-year cooled fuel complies with the requirements in this CSA Standard.
Interim dry storage of irradiated fuel	CSA N292.2 (2013)	The storage of younger than 10-year cooled fuel complies with the requirements in this CSA Standard.

Management of low and intermediate-level radioactive waste	CSA N292.3 (2014)	The storage of younger than 10-year cooled fuel complies with the requirements in this CSA Standard.

Impact of the Storage of Minimum 6-year Cooled Fuel on OPG Governance, Programs and Processes

The table below provides the list of OPG governance, programs and processes that form the licensing basis for PWMF's Waste Management program and identifies the impact of the storage of minimum 6-year cooled fuel on these programs and processes.

Impact of the Storage of Minimum 6-year Cooled Fuel on PWMF's Waste Management Licensing Basis Documents

OPG Waste Management Licensing Basis Document Title	OPG Document Number	Impact from the Storage of Minimum 6-Year Cooled Fuel
Segregation and Handling of Radioactive Wastes	N-PROC-RA-0017	No Change
Management of Waste and Other Environmentally Regulated Materials	OPG-STD-0156	No Change
Nuclear Waste Management	W-PROG-WM-0001	No Change
Radiation Protection	N-PROG-RA-0013	No Change

LC 11.2 Decommissioning Plan

Licence Condition 11.2 states "*the licensee shall maintain a decommissioning plan*" and the details in the PWMF Licence Conditions Handbook (LCH) outline the regulatory requirements. The information provided in the last PWMF licence application is still valid.

List of Decommissioning Related Regulatory Requirements

Licensing Basis Document Title	Document Number	Impact from the Storage of Minimum 6-year Cooled Fuel
Decommissioning of facilities containing nuclear substances	CSA N294-09 (2009)	The storage of minimum 6-year cooled fuel complies with the requirements in this CSA Standard.
Decommissioning of facilities containing nuclear substances	CSA N294-19 (2019)	The storage of minimum 6-year cooled fuel complies with the requirements in this CSA Standard.

Preliminary Decommissioning Plan

As the DSC used to store minimum 6-year cooled fuel remains the same, there is no requirement to update the Preliminary Decommissioning Plan (PDP). The current PWMF PDP does not stipulate the age of the fuel being stored within the DSC.

Impact of the Storage of Minimum 6-year Cooled Fuel on OPG Governance, Programs and Processes

The table below provides the list of OPG governance, programs and processes that form the licensing basis for PWMF's Decommissioning Plan and identifies the impact of the storage of minimum 6-year cooled fuel on these programs and processes.

Impact of the Storage of Minimum 6-year Cooled Fuel on PWMF's Decommissioning Licensing Basis Documents

OPG Waste Management Licensing Basis Document Title	OPG Document Number	Impact from the Storage of Minimum 6-year Cooled Fuel
Decommissioning Program	W-PROG-WM-0003	No Change
Preliminary Decommissioning Plan Pickering Waste Management Facility	92896-PLAN-00960-00001	No Change

LC 12.1 Security Program

Licence Condition 12.1 states "*the licensee shall implement and maintain a security program"* and the details in the PWMF Licence Conditions Handbook (LCH) outline the regulatory requirements. The information provided in the last PWMF licence application is still valid.

List of Security Related Regulatory Requirements

Licensing Basis Document Title	Document Number	Impact from the Storage of Minimum 6-year Cooled Fuel
Nuclear Security Regulations	SOR/2000-209	Compliance documented in Attachment 1
Fitness for Duty, Volume III: Nuclear Security Officer Medical, Physical, and Psychological Fitness	CNSC REGDOC-2.2.4 (2018)	Continued compliance.
High Security Facilities, Volume II: Criteria for Nuclear Security Systems and Devices	CNSC REGDOC-2.12.1 (2018)	Continued compliance.
Site Access Security Clearance	CNSC REGDOC- 2.12.2 (2013)	Continued compliance.

Facilities and Equipment

The storage of minimum 6-year cooled fuel will not require changes to security related facilities, equipment or staffing levels at PWMF.

Response Arrangements

The storage of minimum 6-year cooled fuel will not require changes to security response arrangements or processes.

Impact from the Storage of Minimum 6-year Cooled Fuel on OPG Governance, Programs and Processes

The table below provides the list of OPG governance, programs and processes that form the licensing basis for PWMF's Security program and identifies the Impact from the storage of minimum 6-year cooled fuel on these programs and processes.

Impact from the Storage of Minimum 6-year Cooled Fuel on PWMF's Security Program Licensing Basis Documents

OPG Security Licensing Basis Document Title	OPG Document Number	Impact from the Storage of Minimum 6-year Cooled Fuel
Pickering Waste Management Facility Phase II Security Report	92896-REP-08160-00001	No Change
Pickering Waste Management Facility Security Report Addendum	92896-REP-08160-00001 ADD 001	No Change
Transport Security Plan	TRAN-PLAN-03450- 10000	No Change
Nuclear Security	N-PROG-RA-0011	No Change
Cyber Security	N-PROC-RA-0135	No Change
Nuclear Waste Management Cyber Essential Assets	W-LIST-08161-00001	No Change

LC 12.2 Construction

Licence Condition 12.2 states "*the licensee shall not carry out the activities referred to in paragraph (iii) of Part IV of this licence that relate to completed construction activities in paragraph (iv) of Part IV of this licence until the submission of the proposed security arrangements and measures for the new building, or any potential modifications to the protected area that may be associated with this new building, that is acceptable to the Commission or a person authorized by the Commission"* and the details in the PWMF Licence Conditions Handbook (LCH) outline the regulatory requirements. The information provided in the last PWMF licence application is still valid.

No construction activities will be required as a result of the storage of minimum 6-year cooled fuel at PWMF.

LC 13.1 Safeguards Program

Licence Condition 13.1 states "*the licensee shall implement and maintain a safeguards program"* and the details in the PWMF Licence Conditions Handbook (LCH) outline the regulatory requirements. The information provided in the last PWMF licence application is still valid.

List of Safeguards and Non-Proliferation Related Regulatory Requirements

Licensing Basis Document Title	Document Number	Impact from the Storage of Minimum 6-year Cooled Fuel
Safeguards and Nuclear Material Accountancy	CNSC REGDOC-2.13.1 (2018)	Continued compliance

Nuclear Material Accountancy and Control

All reports and information necessary for safeguards implementation and compliance will continue to be provided to the IAEA and CNSC on a timely basis.

Access and Assistance to the IAEA

Canadian facilities are selected at random by the IAEA for physical inspections to confirm compliance with international non-proliferation requirements. The storage of less than ten-year cooled fuel will have no impact on IAEA inspections or access to IAEA equipment.

Safeguards Equipment, Containment and Surveillance

The storage of minimum 6-year cooled fuel may have some impact on existing IAEA safeguards surveillance monitoring equipment (with respect to temperatures and sealing processes). This is discussed in section LC 3.1 Operating Performance. Analysis in this area continues and OPG continues to work with both the IAEA and CNSC to reach an agreeable outcome.

NuFlash

NuFlash is a system used for tracking nuclear fuel location and storage history. Currently, NuFlash does not allow the preparation of DSC packages for younger than 10-year cooled fuel. The changes required to update the NuFlash database to allow for 100 DSCs to be processed with 6-year to 10-year old fuel will be completed prior to the commissioning of the first DSC containing younger cooled fuel.

Impact from the Storage of Minimum 6-year Cooled Fuel on OPG Governance, Programs and Processes

The table below provides the list of OPG governance, programs and processes that form the licensing basis for PWMF's Safeguards program and identifies the impact from the storage of minimum 6-year cooled fuel on these programs and processes.

Impact from the Storage of Minimum 6-year Cooled Fuel on PWMF's Safeguards Program Licensing Basis Documents

OPG Safeguards and Non- Proliferation Licensing Basis Document Title	OPG Document Number	Impact from the Storage of Minimum 6-year Cooled Fuel
Nuclear Safeguards	N-PROG-RA-0015	No Change
Nuclear Safeguards Implementation	N-STD-RA-0024	No Change

LC 14.1 Packaging and Transport Program

Licence Condition 14.1 states "*the licensee shall maintain a packaging and transport program"* and the details in the PWMF Licence Conditions Handbook (LCH) outline the regulatory requirements. The information provided in the last PWMF licence application is still valid.

Impact from the Storage of Minimum 6-year Cooled Fuel on OPG Governance, Programs and Processes

The table below provides the list of OPG governance, programs and processes that form the licensing basis for PWMF's Packaging and Transport program and identifies the impact of the storage of minimum 6-year cooled fuel on these programs and processes.

Impact from the Storage of Minimum 6-year Cooled Fuel on PWMF's Packaging and Transport Licensing Basis Documents

OPG Transportation and Packaging Licensing Basis Document Title	OPG Document Number	Impact from the Storage of Minimum 6-year Cooled Fuel
Radioactive Material Transportation	W-PROG-WM-0002	No Change
Radioactive Materials Transportation Emergency Response Plan	N-STD-RA-0036	No Change
Radiation Protection	N-PROG-RA-0013	No Change

Section 3: Other Matters of Regulatory Interest

Public Information and Engagement

OPG believes in timely open and transparent communication to maintain positive and supportive relationships and confidence of key stakeholders. OPG's Corporate Relations and Communications organization adheres to the principles and process for external communications as governed by the nuclear standard N-STD-AS -0013, "*Nuclear Public Information and Disclosure*".

List of Public Information and Disclosure Related Regulatory Requirements

Licensing Basis Document Title	Document Number	Impact from the Storage of Minimum 6-year Cooled Fuel
Public Information and Disclosure	CNSC REGDOC-3.2.1 (2018)	Continued compliance

Impact from the Storage of Minimum 6-year Cooled Fuel on OPG Governance, Programs and Processes

The table below provides the list of OPG governance, programs and processes that form the licensing basis for PWMF's Public Information and Disclosure program and identifies the impact of the storage of minimum 6-year cooled fuel on these programs and processes.

Impact from the Storage of Minimum 6-year Cooled Fuel on PWMF's Public Information and Disclosure Licensing Basis Documents

OPG Transportation and Packaging Licensing Basis Document Title	OPG Document Number	Impact from the Storage of Minimum 6-year Cooled Fuel
Nuclear Public Information Disclosure	N-STD-AS-0013	No Change

OPG provides responses to issues and questions raised by stakeholders and the public, and tracks issues and questions to identify trends in order to further refine proactive communications. Two-way dialogue with community stakeholders and residents is facilitated through personal contact, community newsletters, speaking engagements, advertising and educational outreach.

Through this regular outreach of an on-going nature, OPG continues to provide members of the public and interested parties with information regarding activities at the Pickering Waste Management Facility.

Community Committees

The Pickering Community Advisory Council (CAC) meets to exchange information and provide advice to senior station management on station activities as they relate to the adjacent community and public use of the waterfront trail and adjacent lands. Feedback for the waste management facility is obtained through this venue.

OPG also has a representative on the Durham Nuclear Health Committee (DNHC). OPG Nuclear staff make regular presentations to the DNHC on a variety of environmental, community outreach and operational issues. The committee is chaired by the Durham Region Medical Officer of Health.

Community Publications

OPG provides a community newsletter called "Neighbours" on a quarterly basis that are circulated by mail to residents throughout Durham Region (specific to the proximity of the respective nuclear power reactor stations). This provides an update of activities and events that occur at the respective stations.

These forums provide an opportunity for public engagement and information exchange regarding the storage of minimum 6-year cooled fuel at PWMF. Once the Licence Amendment application has been submitted, OPG will communicate the need to store minimum 6-year cooled fuel and status updates to the public through these communication tools.

Indigenous Community Engagement

OPG acknowledges the Aboriginal and Treaty Rights of Indigenous communities as recognized in the *Constitution Act, 1982*. Under its Indigenous Relations Policy, OPG regularly undertakes engagement with Indigenous communities with established or asserted rights and/or interests.

Based on work undertaken through Indigenous engagement, OPG believes the following specific Indigenous Nations and communities continue to have a primary Aboriginal and/or treaty rights and interests with respect to OPG's waste operations at the PWMF:

- Williams Treaties First Nations
- Mohawks of the Bay of Quinte
- Métis Nation of Ontario Region 8

OPG has engaged with these Indigenous communities throughout 2022 and 2023 in order to provide them with information regarding activities at the PWMF (such as the in-service of SB4 in 2021) and to discuss any identified issues and concerns.

Once the Licence Amendment application to store minimum 6-year cooled fuel is submitted to the CNSC, OPG will engage with the Indigenous communities identified above during regular scheduled meetings and briefing to share details on the need and scope of this proposal.

Conclusion

The need to store minimum 6-year cooled fuel at PWMF is an important initiative within OPG to support the Safe Storage Project at PNGS-B. OPG is requesting an amendment of the PWMF WFOL to add a new licensed activity to possess, transfer, package, manage and store minimum 6-year cooled fuel.

OPG is responsible for continued safe operation of the PWMF and confirms that the storage of minimum 6-year cooled fuel will be implemented based on a robust safety case. The proposed activities to support the storage of minimum 6-year cooled fuel will not compromise continued safe operation at PWMF, public and employee safety, and environmental protection.

The safety case for this project can be summarized as follows:

- Design: OPG has and will continue to follow its Engineering Change Control process, to ensure the design complies with applicable PWMF Licence Condition Handbook W4-350.00/2028 regulatory requirements and that configuration management for the facility is maintained.

- Continued Safe Operation: Safety analysis demonstrates that the storage of minimum 6-year cooled fuel will have a negligible effect on safe operation of PWMF, and on public and worker safety.

- Environmental Protection: An assessment of existing environmental-related submissions to the CNSC (environmental assessments, environmental risk assessment and predictive environmental effects assessment) concludes that the storage of younger than 10-year cooled fuel at PWMF will have negligible impact on the environment.

- Licensing Basis: The storage of younger than 10-year cooled fuel at PWMF will have negligible impact on PWMF's licensing basis, governance, programs and processes.

ENCLOSURE #1

OPG Technical Memo
“Storage of Dry Storage Containers (DSCs) containing less than 10 year old used fuel bundles at the Pickering Waste Management Facility (PWMF)”
W-CORR-00531-01662

ONTARIO POWER GENERATION

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OPG Proprietary

Date: July 27, 2020

File No.: W-CORR-00531-01662

Lise Morton
VP Nuclear Waste Management
177 Tie Road, B21
Tiverton, On
N0G 2T0

Dear Lise Morton

Subject: Storage of Dry Storage Containers (DSCs) containing less than 10 year old used fuel bundles at the Pickering Waste Management Facility (PWMF)

References:

1. Letter from D. Howard to K. Talbot, "Pickering Waste Management Facility Thermal Performance Verification Program", dated June 10, 1997. NA44-CORR-N0014035.

2. OPG. Thermal Analysis of an Ontario Power Generation Dry Storage Container Containing Six-Year-Old 28 Or 37 - Element Fuel. Mar 20, 2014. 00104-REP-02308-00007 R00.

3. OPG. Structural Integrity Assessment of a Dry Storage Container Containing Six-Year-Old 28 - Element Fuel. Mar 5, 2014. 00104-REP-79171-00060 R00.

4. OPG. Structural Integrity Assessment of Dry Storage Container (DSC) Containing Six-Year-Old 28-element Fuel Under Postulated On-site Accident Scenarios. Sept 3, 2014. 00104-REP-79171-00061 R00.

5. OPG. Dose Rate Assessment Considering Lower Aged Fuel in PWMF SB3. Jun 15, 2020. 92896-REP-03200-00009 R00.

6. OPG. Email from C. Barua (OPG) to G. Steedman (CNSC). OPG Response To CNSC Question On OPG Submission Cd# 92896-CORR-00531-01355 In Support Of PWMF Safety Report 92896-SR-01320-10002 R006. Jun 29, 2020. 92896-CORR-00531-01381.

Introduction:

The purpose of this memo is to document OPG Environment's recommendation that a stand-alone environmental submission to the CNSC is not needed in order for OPG to perform loading, transfer, and interim storage of used fuel, that has observed a cooling period for a minimum of 6 years, from the Irradiated Fuel Bays (IFBs) to the existing PWMF Used Fuel Storage Building 3 (SB3) (a PWMF Phase II building), until a permanent storage solution becomes available.

The rationale for this decision was based on a review of the following documents:

Environmental assessments (EAs):

- Pickering Waste Management Facility Phase II Final Environmental Assessment Study Report. December 2003. 92896-REP-07701-00002
- Refurbishment and Continued Operation of Pickering B Nuclear Generating Station Environmental Assessment. December 2007. NK30-REP-07701-00002

Environmental Risk Assessment (ERA) and Predictive Effects Assessment (PEA):

- ERA for Pickering Nuclear. Feb 2018. P-REP-07701-00001 R001
- PEA for Pickering Nuclear Safe Storage. April 2017. P-REP-07701-00002 R000

Operating Licences and Handbooks:

- Nuclear Power Reactor Operating Licence. Pickering Nuclear Generating Station. PROL 48.00/2028.
- Pickering Nuclear Generating Station Nuclear Power Reactor. Licence Conditions Handbook. LCH-PR-48.00/2028-R000.
- Waste Facility Operating Licence. Pickering Waste Management Facility. WFOL-W4-350.0/2028.
- Pickering Waste Management Facility. Licence Conditions Handbook. LCH-W4-350.00/2028.

Record of Proceedings and Record of Decision:

- Record of Proceedings, Including Reasons for Decision. May 28, 2004. Subject: Environmental Assessment Screening Report on the proposed expansion of the Pickering Waste Management Facility (Phase II). Available online: http://www.nuclearsafety.gc.ca/eng/the-commission/pdf/Decision-OPG-PWMF-e.pdf

- Record of Proceedings, Including Reasons for Decision. December 10, 2008. Subject: Screening Environmental Assessment of the Pickering Nuclear Generating Station B Refurbishment and Continued Operations Project, Pickering, Ontario. Available online: http://www.suretenucleaire.gc.ca/eng/the-commission/pdf/2008-12-10-Decision-PickeringB-e-Edocs3330500.pdf

- Record of Decision. April 13, 2017. Subject: Application to Renew the Waste Facility Operating Licence for the Pickering. Available online: http://nuclearsafety.gc.ca/eng/the-commission/pdf/2017-04-13-Decision-OPG-PickeringWasteManagementFacility-e.pdf

Relevant sections considered in the above documents are presented in Attachment A (section A1 – A6).

Background:

As a common practice, used fuel from operating units at the Pickering Nuclear Generating Station (PNGS) is cooled in the IFBs for a minimum of 10 years before being transferred into DSCs, and placed into interim storage buildings in the PWMF. This practice is described in the PWMF Phase II EA, Pickering B Refurbishment and Continued Operation EA, Pickering Nuclear ERA, Pickering Nuclear Safe Storage PEA, and the Record of Proceedings associated with the EA of the Pickering B Refurbishment and Continued Operations**.**

Loading and interim storage of a DSC containing four modules of 6-year-old used fuel was successfully completed in May 1998 at the PWMF. Authorization at the time was given by Atomic Energy Control Board (AECB) (Reference 1). Repeating this infrequent practice in the future will enable OPG to create additional space in the IFB-B to allow for storage of fuel from Unit 5 to 8 to support permanent shutdown of the PNGS and planning of Pickering Safe Storage.

Summarized below is the outcome of the review.

Project scope

There is no change in project scope as described in the EA's. The project scope includes used fuel transfer and interim storage in the PWMF. It does not specify the age of the fuel allowed for transfer and storage. Refer to attachment A section A1 for more details.

Licensed activities and conditions:

There is no change to licensed activities and conditions. The Pickering Operating Licence and the WWMF Operating Licence together covers the transport, packaging, management and interim storage of the nuclear fuel. Loading and storing younger used fuel will not deviate from any of the licence conditions. Refer to attachment A section A2 for more details.

Cooling period of used fuel:

Although various documents (i.e. EA's, ERA, PEA, Record of Proceedings) describe how used fuel is cooled in the IFBs for a minimum of 10 years before being loaded, transferred, and stored (see attachment A section A3), it is still possible to initiate and implement a change to this current practice via existing OPG processes (e.g., Engineering Change and Control (ECC)).

Since the change to reduce the cooling period is not considered a ‘Designated Project’ under the Canadian Impact Assessment Act (IAA), there is no requirement to conduct an EA (or now referred to as an IA) under the Impact Assessment Act. Past EA’s were completed as part of the licence application process to support their respective licensing decisions. Once the licensing decisions are made, EAs are not revised.

The 2017 ERA was provided to CNSC to support the PWMF and Pickering operating licence renewal application and an ERA is required to be routinely updated every 5 years as per RegDoc 2.9.1 (Environmental Principles, Assessment and Protection Measures). The routine ERA updates for PN will consider any impacts from recent changes in operational activities including fuel loading, transfer and storage. A decision is expected to be made in 2021 on whether there is a need to update the PEA based on any known activities that may potentially invalidate the bounding scenarios or assumptions made in the PEA. The change identified in this memo will be assessed as part of that decision.

Fuel integrity:

Younger used fuel is expected to have a higher thermal temperature than older used fuel. It is mentioned in the EA (92896-REP-07701-00002) that the temperature of the fuel in dry storage is an important factor in the assurance of fuel integrity and safety and a temperature of up to 300ºC can be considered safe. A maximum and conservative fuel sheath temperature of about 272ºC is predicted based on a thermal analysis of a DSC containing 6-year-old fuel (Reference 2), which is less than the 300ºC limit mentioned in the EA. Thermal stresses produced from 6 year old fuel stored in a DSC is also predicted not to compromise the containment and radiation shielding functions of the DSC under processing and storage accident conditions based on structural integrity analysis completed (Reference 3 and Reference 4).

As long as the fuel sheath temperature remains under the upper limit of 300ºC, there should be no additional environmental risks associated with fuel integrity. Refer to Attachment A section A4 for more details on the fuel integrity related descriptions found in the EAs.

Dose rates:

DSCs containing younger used fuel may have higher dose rates compared to those without depending on the average age and arrangement of used fuel bundles inside in the DSCs. The predicted dose rates and annual doses from SB3 (from a bounding scenario that includes storage of 100 DSCs containing only 6 year old decayed used fuel in SB3) are still well within the regulatory limit (i.e., 1 mSv/y for a member of the public). Dose rates at the existing protected area fence for the SB3 bounding scenario are expected to remain well within the radiation dose rate targets of ≤ 0.5 μSv/h at the PWMF II perimeter fence and ≤ 100 μSv/y at the PNGS site boundary, as proposed in recent communication with the CNSC (Reference 6). Dose rates at the Phase II protected area fence will continued to be measured and monitored and mitigating actions taken if required.

The storage of younger fuel will not pose an unacceptable risk to workers or members of the public nor will it likely to result in adverse effects on the environment provided that the ECC process and the ALARA principle are followed and that all the relevant conditions under the Pickering Nuclear and PWMF Operating Licences (e.g., to implement and maintain the radiation protection program, environmental protection program, waste management program, and packaging and transport program) continue to be met.

For more details on the dose rate predictions, see shielding assessment for PWMF using lower fuel age in SB3 (Reference 5). For more details on the dose rate related assessments completed in the past EA's and the relevant regulatory limit and targets, see attachment A section A5. For more details on the licence conditions, see attachment A section A1

Conclusion:

A stand-alone environmental submission to CNSC is not required since loading, transporting, and storage of used fuel, 6 year or older, is considered to be within the scope of the relevant project EAs and falls within the conditions of the Pickering Nuclear and PWMF Waste Operating Licences.

Prior to the implementation of the plan to load, transfer, and store younger used fuel, the PWMF Safety Report will be updated and the OPG ECC process will be followed to demonstrate that OPG will be able to maintain an adequate level of safety. Changes to existing governance stemming from the plan to load, transfer and store used fuel with a shorter cooling period than 10 years will also be managed through the ECC process.

Sincerely,

RMcCalla

Raphael McCalla
Director
Environment Nuclear

RM/sl

cc. Cammie Cheng
Jason Wight
Paul Crowley
Rafi Asadi
Kapil Aggarwal
Mark Priest
Steve Bagshaw
Mark Ferry
Ram Kalyanasundaram
Cameron Spence

Attachment A

Supporting Information

Section A1

Scope of the Project:

SOURCE: Pickering Waste Management Facility Phase II Final Environmental Assessment Study Report. December 2003. 92896-REP-07701-00002

1.3.1 Scope of the Project

The physical works involved in this project are the storage buildings to be built for the dry storage containers; all facilities, systems and activities required for the construction and operation of PWMF II; and the facilities, systems and activities required for the construction and operation of PWMF Phase II; and the facilities, systems, and activities involved in the transfer of loaded welded DSCs from PWMF I to the storage buildings in PWMF II.

Associated operations and activities that are within the scope of the project include:

- Preparation of systems and facilities involved in the transfer of loaded welded DSCs
    - o Transfer of loaded welded DSCs from the Processing Workshop or Storage Buildings 1 and 2 in PWMF I to Storage Buildings 3 and 4 in PWMF II.

SOURCE: Refurbishment and Continued Operation of Pickering B Nuclear Generating Station Environmental Assessment. December 2007. NK30-REP-07701-00002

1.4.2 Scope of the Project

The physical works for the Project are the PNGS B Units 5, 6, 7 and 8 and ancillary systems necessary for their operation through to about 2060.

As outlined in the EA Guidelines (Section 7.0, p.5), the scope of project will consider the following activities related to the continued operation of the refurbished reactors until about 2060, including:

- continued interim storage of used fuel at the Pickering Used Fuel Dry Storage Facility (PUFDSF) within the PWMF;
- interim storage for the additional used nuclear fuel and the refurbishment waste at the PWMF;

Section A2

Licensed activities and conditions

SOURCE: Nuclear Power Reactor Operating Licence Pickering Nuclear Generating Station PROL 48.00/2028

IV) LICENSED ACTIVITIES:

This licence authorizes the licensee to:

(i) operate the Pickering Nuclear Generating Station (hereinafter "the nuclear facility") at a site located in the City of Pickering, in the Regional Municipality of Durham, in the Province of Ontario;

(ii) possess, transfer, use, package, manage and store the nuclear substances that are required for, associated with, or arise from the activities described in (i);

(vi) transport Category II nuclear material by road vehicle from the nuclear facility spent fuel bay to the onsite waste storage facility;

VI) CONDITIONS:

4. Safety Analysis
4.1 The licensee shall implement and maintain a safety analysis program.

7. Radiation Protection
7.1 The licensee shall implement and maintain a radiation protection program, which includes a set of action levels. When the licensee becomes aware that an action level has been reached, the licensee shall notify the Commission within seven days.

9. Environmental Protection
9.1 The licensee shall implement and maintain an environmental protection program which includes a set of action levels. When the licensee becomes aware that an action level has been reached, the licensee shall notify the Commission within seven days.

11. Waste Management
11.1 The licensee shall implement and maintain a waste management program.

14. Packaging and Transport
14.1 The licensee shall implement and maintain a packaging and transport program.

SOURCE: Licence Conditions Handbook (LCH-PR-48.00/2028-R000) - Pickering Nuclear Generating Station Nuclear Power Reactor Operating Licence

Licence Condition G.1: Nuclear Substances

Activity (ii) in the licence authorizes the licensee to possess, transfer, use, package, manage and store nuclear substances.

Activity (vi) in the licence authorizes the licensee to transport Category II nuclear material i.e. fuel by road from Pickering NGS spent fuel bay to the onsite waste storage facility, The Pickering waste storage facility is licensed separately from the Pickering NGS licence (WFOL-W4-350.02/2018 – e-Doc 4002929). This activity is addressed as part of LC 14.1, which describes the packaging and transport program.

Licence Condition 14.1: Packaging and Transport Program

The licensee shall implement and maintain a packaging and transport program.

Preamble:

Every person who transports radioactive material, or requires it to be transported, shall act in accordance with the requirements of the Transportation of Dangerous Goods Regulations (TDGR) and the Packaging and Transport of Nuclear Substances Regulations, 2015 (PTNSR 2015).

The PTNSR 2015 and the TDGR provide specific requirements for the design of transport packages, the packaging, marking and labeling of packages and the handling and transport of nuclear substances.

The packaging and transport SCA includes the following specific areas (SpAs):
• Package design and maintenance;
• Packaging and transport; and
• Registration for use.

Compliance Verification Criteria:

Licensee Documents that Require Notification of Change		
Document #	**Title**	**Prior Notification**
W-PROG-WM-0002	Radioactive Material Transportation	No
N-STD-RA-0036	Radioactive Materials Transportation Emergency Response Plan	No

Package Design and Maintenance:
PTNSR 2015 apply to the packaging and transport of nuclear substances, including the design, production, use, inspection, maintenance and repair of packages, and the preparation, consigning, handling, loading, carriage and unloading of packages. Where necessary, OPG package designs are certified by the CNSC

Packaging and Transport (Program):
The licensee shall implement and maintain a packaging and transport program that will ensure compliance with the requirements of the TDGR and the PTNSR 2015 for all shipments of nuclear substances to and from the Pickering NGS site. Shipments of nuclear substances within the nuclear facility where access to the property is controlled are exempted from the application of TDGR and PTNSR 2015.

Registration and Use:
OPG's packaging and transport program also covers the registration for use of certified packages as required by the regulations.

Guidance:

Org / Document #	Title	Version
CNSC / REGDOC 2.14.1	Information Incorporated by Reference in Canada's Packaging and Transport of Nuclear Substance Regulations, 2015	2016

SOURCE: Waste Facility Operating Licence Pickering Waste Management Facility – WFOL-W4-350.0/2028

IV) LICENSED ACTIVITIES:

This licence authorizes the licensee to:

(i) operate the Pickering Waste Management Facility ("the facility") located at the Pickering Nuclear Generating Station, City of Pickering, Regional Municipality of Durham, Province of Ontario;

(ii) possess, transfer, use, process, package, manage, and store nuclear substances that are required for, associated with or arise from the activities described in (i);

(iii) transport Category II nuclear materials that are associated with the activities described in (i) on the site of the Pickering Nuclear Generating Station;

VI) CONDITIONS:

4 Safety Analysis
4.1 Safety Analysis Program
The licensee shall implement and maintain a safety analysis program.

7 Radiation Protection
7.1 Radiation Protection
The licensee shall implement and maintain a radiation protection program, which includes a set of action levels. When the licensee becomes aware that an action level has been reached, the licensee shall notify the Commission within seven days.

9 Environmental Protection
9.1 Environmental Protection

The licensee shall implement and maintain an environmental protection program, which includes a set of action levels. When the licensee becomes aware that an action level has been reached, the licensee shall notify the Commission within seven days.

10 EMERGENCY MANAGEMENT AND FIRE PROTECTION
10.1 Emergency Preparedness Program
The licensee shall implement and maintain an emergency preparedness program.
10.2 Fire Protection Program
The licensee shall implement and maintain a fire protection program.

11 Waste Management
11.1 Waste Management Program
The licensee shall implement and maintain a waste management program.

14 Packaging and Transport
14.1 Packaging and Transport Program
The licensee shall implement and maintain a packaging and transport program.

SOURCE: Pickering Waste Management Facility Licence Conditions Handbook LCH-W4-350.00/2028

Licence Condition 4.1 Safety Analysis Program

Compliance Verification Criteria
Licensee Documents that Require Notification of Change

Doc#	Title	Prior Notice
92896-SR-01320-10002	Pickering Waste Management Facility – Safety Report	Y

Licensing Basis Publications

Org	Doc#	Title
CSA Group	N292.0-14	General principles for the management of radioactive waste and irradiated fuel
CSA Group	N-292.2-13	Interim dry storage of irradiated fuel

The safety analysis report is to confirm that the consequences of a range of events are acceptable. It includes an integrated assessment of the facility to demonstrate, among other things, adequate safety for external events such as fires, floods, and tornados, and adequate protective features to ensure the effects of an event do not impair safety related systems, structures, and components (SSC).

Every 5 years, OPG shall submit a revised safety analysis report for the facility. CNSC staff review the safety analysis report to verify that OPG employs appropriate assumptions, applies adequate scope, and demonstrates acceptable results. The safety analysis report must demonstrate that the radiological consequences of accident scenarios do not exceed public dose limits.

Licensees shall carry out safety analyses to confirm that facility design changes will not result in a reduction of safety compared to the licensing basis, as per LC G.1. The safety analysis report shall:

- demonstrate compliance with public dose limits, the dose-related criteria, structural-integrity related criteria, the limits on process and safety parameters, and safety or safety-related system requirements;
- justify appropriateness of the technical solutions employed in the supporting justification of safety requirements; and,
- complement other analyses and evaluations in defining a complete set of design and operating requirements.

Licence Condition 7.1 Radiation Protection

The Radiation Protection Regulations require that the licensee implement a radiation protection program and also ascertain and record doses for each person who perform any duties in connection with any activity that is authorized by the NSCA or is present at a place where that activity is carried on. This program must ensure that doses to persons (including workers) do not exceed prescribed dose limits and are kept As Low As Reasonably Achievable (the ALARA principle), social and economic factors being taken into account.

The regulatory dose limit to workers and the general public are explicitly provided in sections 13, 14 and 15 of the Radiation Protection Regulations.

Licence Condition 11.1 Waste Management Program

With respect to the storage and management of spent nuclear fuel, the waste management program should reflect the fundamental safety concerns related to criticality, exposure, heat control, containment, and retrievability. That is, the systems that are designed and operated should assure subcriticality, control of radiation exposure, assure heat removal, assure containment, and allow retrievability.

Licence Condition 14.1 Packaging and Transport Program

Compliance Verification Criteria
Licensee Documents that Require Notification of Change

Doc#	Title	Prior Notice
W-PROG-WM-0002	Radioactive Material Transportation	N
N-STD-RA-0036	Radioactive Materials Transportation Emergency Response Plan	N
N-PROG-RA-0013	Radiation Protection	Y

Section A3

Description on the cooling duration of used fuel in IFBs:

SOURCE: ERA for Pickering Nuclear. Feb 2018. P-REP-07701-00001 R001

2.2.2.1.1 Used Fuel

Used fuel bundles are initially 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

SOURCE: PEA for Pickering Nuclear Safe Storage. April 2017. P-REP-07701-00002 R000

1.0 Introduction

Following shutdown, the activities at PN Generating Station would involve the four distinct phases outlined below.

1) A 2-3 year ***Stabilization Phase*** per unit to transition each unit, and the station as a whole, from their current operating states to their respective safe storage states. Stabilization activities will include defuelling and dewatering reactor units.

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

1.1 Project Overview

Many of the specific details of the Stabilization activities are not finalized; however, assumptions have been made to provide a conservative (i.e., worst case) assessment of effects resulting from the transition and safe storage state.

Activities specific to the Stabilization Phase include:

- removal of all nuclear fuel from the reactor units and transfer to the IFBs and auxiliary irradiated fuel bay (AIFB);

Activities during the Storage with Surveillance Phase include:

- continued operation/surveillance of the IFBs, including transfer of used fuel from the IFBs to DSCs for storage on the PWMF site. It is anticipated that the irradiated fuel bays will be required for up to 10 years of cooling;

1.3 PEA Goals, Approach and Scope

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

3.0 Stabilization and Storage with Surveillance Activities

The main elements of the Stabilization and Storage with Surveillance Phases include the following.

- Removal of all nuclear fuel from the reactor units and transfer of the fuel to an IFB for approximately up to 10 years of cooling. Continued operation/surveillance of the IFBs and AIFB are required until all irradiated fuel and other components stored in the fuel bays are transferred into DSCs for safe interim storage at the PWMF.

3.13 Pickering Waste Management Facility

Used fuel bundles will continue to be stored in an IFB up to 10 years and then transferred to DSCs for interim storage in the PWMF.

SOURCE: Pickering Waste Management Facility Phase II Final Environmental Assessment Study Report. December 2003. 92896-REP-07701-00002

Section 2.2.2.1 Development Background

Since 1996, used fuel that has been cooled for at least ten years in PN's IFBs has been routinely transferred into DSCs for dry storage at PWMF I.

Appendix C – Community and Stakeholder Consultation

C-6 Newsletters

PWMFII EA NEWS - May 2002, Issue One

When used fuel bundles are removed from the reactors at Pickering Nuclear, they are still highly radioactive. They have to be managed safely and responsibly for a long time. The first step is to cool the fuel bundles under water for up to 10 years in specially engineered used fuel bays. As the Pickering fuel bays become full, it is necessary to transfer the used fuel from the fuel bays to robust concrete and steel containers for dry storage in a specially designed facility on the station site.

C-6 Newsletters

PWMFII EA NEWS - September 2003, Issue Three

The initial used fuel dry storage facility, PWMF I, has been in operation since 1996. The facility uses a dry storage process that is a proven, safe and regulated technology, widely used by other nuclear facilities in Canada, the USA and other countries. The process involves removing used fuel bundles from the water-filled used fuel storage bays (after a minimum of 10 years in those bays) at PN and placing them in specially designed robust steel and concrete containers called "Dry Storage Container" or DSCs. The DSCs are then processed, sealed and transferred to the Used Fuel Dry Storage buildings.

C-7 Project Information Package

When used fuel bundles are removed from the reactors at Pickering Nuclear, they are still highly radioactive. They have to be managed safely and responsibly for a long time. The first step is to cool the fuel bundles under water for up to 10 years in specially engineered used fuel bays. As the Pickering fuel bays become full, it is necessary to transfer the used fuel from the fuel bays into robust concrete and steel containers and store them in a specially designed storage facility on the station site. The containers – called “Dry Storage Containers” (DSCs) - are engineered to last at least 50 years and will provide safe, interim storage until a long-term management program is in place.

Used fuel is stored for at least 10 years under water in fuel bays at Pickering Nuclear. The water keeps the fuel bundles cool and provides an effective radiation shield. This is normal practice at all OPG nuclear stations and elsewhere.

C-11 Presentation to the PN Community Advisory Council (CAC)

<u>Presentation to Community Advisory Council - February 19, 2002</u>

> After 10 years, the used fuel may be moved to dry storage, on site but separate from station operations.

<u>Pickering Nuclear Generating Station Community Advisory Council</u>
Pickering Nuclear Information Centre - March 18, 2003
Meeting Highlights

> Council Comment and Questions
> John Peters and Don Gorber responded to Council comments and questions:
>
> - How did the EA address the effect of radiation over time?
>
>   John: The contribution of PWMF II to gamma radiation over time depends on the age of the used fuel when it is loaded into the container. The EA took the worst case for calculating PWMF II contribution per year, fuel that is only 10 years old and put into the facility all at once.

Appendix D - Open House Information Panels

Phase II of the Pickering Waste Management Facility will:

- Be used to store only Pickering used fuel and only after it has spent at least ten years in the existing fuel bays within the stations (wet storage)

Appendix G – Review comments on draft EA Study Report and OPG’s Responses

Comments from IER & Scimus Inc. in association with North-South Environmental on behalf of the City of Pickering, July 2003 on the PWMF II Draft EA Study Report

IER comment:

> The total capacity of the storage buildings is 1654 Dry Storage Containers (DSC’s), only 7% more than the total number of DSC’s expected. This does not appear to provide sufficient contingency against unforeseen problems (Section 2.2.1, page 2-1).

OPG response:

OPG maintains an overall nuclear waste system plan which includes all waste streams that it manages. Part of the plan addresses contingency plans for all phases of used fuel management. The dry storage step is only for used fuel that has been cooled for at least 10 years in wet storage, so there is a long lead time in determining requirements for additional storage capacity. If additional storage capacity was needed in the future another storage building could be proposed after 2016 when SB #4 was commissioned, but before 2025 when all the SBs at PN are filled to capacity. No change in the EA Study Report is required.

SOURCE: Refurbishment and Continued Operation of Pickering B Nuclear Generating Station Environmental Assessment. December 2007. NK30-REP-07701-00002

2.12 Basis for the Environmental assessment

Table 2.12-1, referred to as the "Basis for Environmental Assessment", provides a listing and description of each of the works and activities associated with the Project. This information provides the basis for the assessment of the effects on each of the environmental components.

Table 2.12-1 Basis for EA Study

Project Phase / Works and Activities - Interim Storage of Used Fuel at PWMF:

Irradiated fuel is stored in the irradiated fuel storage bay for a minimum period of 10 years before being transferred to Dry Storage Containers (DSCs) for interim storage at PWMF until a long-term storage facility is available.

SOURCE: Record of Proceedings, Including Reasons for Decision. December 10, 2008. Subject: Screening Environmental Assessment of the Pickering Nuclear Generating Station B Refurbishment and Continued Operations Project, Pickering, Ontario

107. To address concerns raised by several intervenors on waste management, the Commission requested that OPG elaborates on the design of the dry-storage container used for used fuel storage and on the fuel cycle after the removal of fuel from the reactor…… To answer the fuel cycle portion of the question, OPG added that the fuel removed from the reactor is stored in water pools at the stations for a minimum of 10 years to allow the fuel to cool to about 0.1 % of the radioactivity levels present at the time of its removal from the reactor. The fuel is then transferred to dry-storage containers for storage until a disposal facility is available.

Section A4

Description on integrity of used fuel:

SOURCE: Pickering Waste Management Facility Phase II Final Environmental Assessment Study Report. December 2003. 92896-REP-07701-00002

2.3.1.1 DSC Design and Operating Conditions

The DSC provides the necessary radiation shielding and containment of radioactive materials. It is designed to provide a storage life of at least 50 years and to meet all shielding and containment integrity requirements over this period.

To permit future retrieval, used fuel bundles in dry storage need to remain structurally intact and retain sufficient strength to sustain the stresses associated with future handling and transport. This requires limiting cladding deformation by creep or other degradation processes such as oxidation in the uranium dioxide fuel pellets. The integrity of used fuel cladding is also a key requirement for radiological safety. The pellet and the zircaloy sheath provide a primary barrier to prevent the release of radionuclides. The DSC provides secondary containment for any radionuclides released by the fuel, in the event that the fuel cladding integrity was compromised.

Both cladding creep and fuel matrix oxidation, the processes that could lead to splitting of the fuel cladding, resulting in release of radionuclides into the DSC cavity, are temperature dependent processes. Therefore, the temperature of the fuel in dry storage is an important factor in the assurance of fuel integrity and safety. The provisions used to maintain used fuel integrity during storage include welded closure of the DSC and the addition of an inert helium atmosphere in the DSC cavity. Oxidation is also limited due to helium.

Analysis and measurements carried out at PUFDSF indicate that the maximum fuel cladding temperature does not exceed 175ºC in dry storage. When used fuel is stored in a helium atmosphere, temperatures of up to 300ºC can be considered safe for the planned storage period for intact used fuel in DSCs. The upper temperature limit ensures that creep strain remains within acceptable limits. The inert gas precludes oxidation processes. These storage conditions are also considered safe for dry storage of used fuel with minor cladding defects. The above considerations support the conclusion that under normal operating conditions, DSCs provide safe and retrievable storage for OPG's used nuclear fuel.

2.3.1.2 Factors Influencing Long-Term Integrity of the DSC and Used Fuel

The DSC has been designed to provide a storage life that will meet all shielding and containment integrity requirements over a minimum 50 year service life. Investigations were performed during DSC design regarding the integrity and stability of the DSC for different load cases over the 50 year service life. The DSC design is based on analyses of a range of considerations concerning the following:

- decay heat removal
- shielding
- containment
- structural integrity

2.3.1.3 DSC and Fuel Integrity under Credible Malfunction and Accident Scenarios

As part of the design process for the DSC, load scenarios approximating a range of potential accidents and malfunctions were studied. The scenarios included DSCs in a range of dry storage scenarios, and in a range of transfer methods.

Section A5

Dose, radiation, environmental effects, and mitigation:

SOURCE: Pickering Waste Management Facility Phase II Final Environmental Assessment Study Report. December 2003. 92896-REP-07701-00002

2.3.2.2 Radiation and Radioactivity Considerations in PWMF II Design

Radiation Shielding

The radiation dose rate targets for PWMF II, derived for a member of the general public, are as follows:

- ≤ 0.5 μSv/h at the PWMF II perimeter fence, based on maximum 2000 hours per year occupancy for non-Nuclear Energy Workers (non-NEWs),
- ≤ 10 μSv/y contribution at the PNGS exclusion zone boundary; this dose rate target is 1% of the CNSC dose rate limit of 1 mSv/y for a member of the public.

5.2.4.2 Regional/Local Study Area - Workers at PNGS and the PWMF I

The average individual doses to Nuclear Energy Workers (NEWs) at PNGS from both internal (i.e., inhaled or ingested) and external exposure sources were reported at 1.1 mSv/y, and the maximum individual dose was reported at 10 mSv in 2001. T hese doses are consistent with OPG's Exposure Control Level (ECL) of 10 mSv/y per calendar year, and are well below the CNSC regulatory limit of 50 mSv in any calendar year and 100 mSv over five calendar years (Canada Gazette 2000).

The baseline annual individual doses to workers (NEWs) at the PWMF I were taken from monitoring data. During 2001, nine operators at the PWMF I received an average individual dose of 0.64 mSv with a maximum of 1.94 mSv. Six mechanical maintainers who worked in the PWMF I reported measurable doses, with an average of 0.14 mSv and a maximum of 0.45 mSv (OPG 2002d). These occupational doses are consistent with OPG's ECL, and are well below the regulatory limit of 50 mSv in any calendar year and 100 mSv over five calendar years.

5.2.5.2 Site Study Area

The baseline dose from the existing environment to non-human biota in the Siting Area is attributable to two sources: i) natural background radiation and radioactivity (described in Section 5.2.5.1), and ii) licensed nuclear activities on the site.

Dose rates to biota in the Siting Area from radioactivity releases from the PNGS are attributable to external gamma radiation from radioactive noble gases, and from uptake and internal exposure to tritium and carbon-14; these dose rates were estimated at 0.11 μGy/d. The gamma dose rate (direct and skyshine gamma radiation) in the Siting Area from PWMF I was estimated at 0.03 μGy/d. The total dose rate from these sources was estimated at 0.14 μGy/d in this assessment.

In conclusion, the baseline dose to terrestrial fauna in the Siting Area was calculated to be 4.1 μGy/d, with over 90% of that contributed by natural background radiation and radioactivity. The corresponding dose to terrestrial flora was estimated in the range 1.8 to 20 μGy/d, also predominantly from natural background

7.3.1 Radiation and Radioactivity: Atmospheric Environment

7.3.1.2 Operations Phase – Likely Environmental Effects

The design of the Storage Buildings will provide for sufficient concrete shielding in the walls up to 30 cm (12") such that the gamma radiation level at the perimeter of the PWMF II site is predicted to be 0.13 µSv/h (Nuclear Safety Solutions 2003). This level meets the OPG target of < 0.5 µSv/h, corresponding to a dose < 1,000 µSv/y for 2000 h/y occupancy, the CNSC public dose limit (applicable for non-NEWs).
A dose rate of up to 50 µSv/h was predicted at the roof (Nuclear Safety Solutions 2003). This value was adopted in this assessment as a conservative estimate (i.e., overestimate) of the corresponding dose rate at the PWMF II. The predicted gamma radiation levels from full Storage Buildings located at Site Area B provides a dose rate of < 10 µSv/y at the PN east property boundary. This includes both direct and skyshine contributions. This is expected to increase the levels by less than three percent above a baseline of 350 µGy/y and will be indistinguishable from the temporal and spatial variations in natural background radiation levels at this location.

Identified Mitigation Measures
The gamma radiation from the DSCs was determined to be indistinguishable from background radiation levels at the PN east property boundary. The calculated dose rate meets OPG's dose targets and is well within CNSC's regulatory limit. Therefore, no mitigation measures are required.

7.3.2 Radiation and Radioactivity: Terrestrial Environment

7.3.2.2 Operations Phase – Likely Environmental Effects

The terrestrial environment will be affected by gamma radiation from DSCs. The effect of gamma radiation on the terrestrial environment from the operation of two Storage Buildings containing the full complement of loaded DSCs (approximately 1000) serves as the upper bound for both Project Works and Activities, including transfer of DSCs between PWMF I and PWMF II. The potential effects on birds perching on the roof, on flora and fauna at the exterior walls, and on flora and fauna at the perimeter of the PWMF II site boundary are described below.

Birds may perch on the roof of the Storage Buildings for brief periods, and be exposed to absorbed dose rates of approximately 0.05 mGy/h from gamma radiation. Exposure periods of one or two hours per day would result in dose rates of up to 0.2 mGy/d. This dose rate is less than the no-effect-level of 1 mGy/d reported by UNSCEAR (1996). Based on observations since the beginning of operation of PWMF I in 1996, birds have not nested on the roof of the PWMF I Storage Buildings 1 and 2, and therefore, are not expected to nest on the roof of the PWMF II.

The effects of gamma radiation on flora and on fauna with a limited range (e.g., field mouse) that live in the vicinity of the perimeter of the PWMF II site was evaluated by comparing estimated doses to no-effect levels reported by UNSCEAR. Fauna with a large range spend some of their time at distance from the Storage Buildings in lower radiation fields, and are expected to receive lower daily doses than the biota confined to the areas adjacent to the perimeter of the PWMF II site. Based on the assessment of the gamma radiation levels from loaded DSCs in the PWMF II Storage Buildings at the perimeter of the PWMF II site, the estimated daily dose rate to flora and fauna at that location is approximately 0.004 mGy/d. This is a small fraction of the no-effects level of 1 mGy/d reported by UNSCEAR (1996). This dose rate is expected to be within the range of natural background levels. Thus, the additional dose will be indistinguishable from the temporal and spatial variations in natural background radiation levels at this location.

Identified Mitigation Measures
Since the doses to flora and fauna are expected to be less than no-effect levels reported by UNSCEAR, no mitigation levels are required.

7.3.3 Radiation Doses to Members of the Public

7.3.3.2 Operations Phase - Likely Environmental Effects

Members of the public living and working outside the PN property boundary could potentially be affected by gamma radiation from DSCs during both of the Project Works and Activities listed above. The effect of gamma radiation on members of the public from two Storage Buildings containing the full complement of loaded DSCs (i.e., approximately 1000) serves as an upper bound for effects of both Project Works and Activities under normal operations. To ensure that all members of the public living, working or undertaking recreational activities beyond the PN property boundary are protected, a conservative estimate of the radiation dose to a hypothetical individual located year round at the PN east property boundary was compared to regulatory limits.

At the closest point on the site boundary to the PWMF II on Site Area B, the estimated annual dose from PWMF II, to a hypothetical individual located year round at the PN east property boundary was < 10 µSv (Nuclear Safety Solutions 2003), which is less than 1% of the CNSC regulatory limit of 1000 µSv/y. This annual dose is also below the level of regulatory concern of 10 µSv/y as recommended by the ACRP/ACNS (1988), and meets OPG's target of < 10 µSv/y for a member of the public.

The baseline dose to the hypothetical individual, as described in Section 5.2.4, is approximately 1,300 µSv/y from natural background radiation, and approximately 4.8 µSv/y from existing licensed operations at PN (OPG 2003d); therefore, the additional dose from the PWMF II project (< 10 µSv/y) is expected to be a very small fraction of the dose from natural background radiation, and will be indistinguishable from the temporal and spatial variations in radiation levels at this location (Figure 7.3-1).

Identified Mitigation Measures

Since it was determined that the additional dose from PWMF II to members of the public living, working or undertaking recreational activities outside the PN property boundary is expected to be a very small fraction of the dose from background radiation, it will be indistinguishable from the temporal and spatial variations in radiation levels. Therefore, no mitigation measures are required.

7.3.4 Radiation Doses to Workers

7.3.4.2 Operations Phase - Likely Environmental Effects

<u>Workers (NEWs) Directly Involved with PWMF II</u>

Doses to workers during normal operation at PWMF II were conservatively estimated on the basis of measured doses to workers at the PWMF I where similar activities to those identified for the PWMF II are carried out.

The individual doses to operators at PWMF II are expected to average 0.64 mSv/y with a maximum of 1.9 mSv/y. Individual doses to mechanical maintainers at PWMF II are expected to average 0.14 mSv/y with a maximum of 0.45 mSv/y. These annual doses to workers at PWMF II from normal operation are expected to be a small fraction of the regulatory limits, and well below OPG's ECL of 10 mSv/y.

<u>PNGS Workers (NEWs)</u>

The additional dose to individual PNGS workers from normal operation of the PWMF II (i.e., < 0.64 mSv/y) will be in addition to the baseline average annual dose received by PNGS workers of 1.1 mSv/y with a maximum of 10 mSv/y. Therefore, the average individual dose to a PN worker is predicted to be approximately 1.7 mSv/y (i.e., the sum from both activities). This is considered to be an over-estimate as the additional dose to PNGS workers from the PWMF II is expected to be much less than the average dose to workers at PWMF II. The doses from normal operation at PWMF II to PNGS workers (NEWs) are a small fraction of the CNSC's regulatory limit and OPG's ECL. Internal and external doses received by PNGS workers are monitored and reported as part of their cumulative annual dose.

PN Workers (non-NEWs)
PN workers (non-NEWs) who work outside the protected areas of the PWMF II and the PN will be exposed to low levels of gamma radiation from the PWMF II activities listed above and are subject to CNSC's regulatory limits on an annual dose of 1 mSv. The gamma dose rate at the security fence of the PWMF II will be maintained at levels below the OPG target of < 0.5 µSv/h (1,000 µSv for a 2,000 hour work year) (Nuclear Safety Solutions 2003). Therefore, the effects of normal operation of PWMF II on PN workers (non-NEWs) are expected to be below the regulatory limit.

Identified Mitigation Measures
Because the estimated doses to workers (both NEWs and non-NEWs) during normal operations at PWMF II were determined to be below CNSC's regulatory limits and below OPG's ECLs, no mitigation measures are required.

8.4 Radiation Dose Related to Radiological Malfunctions and Accidents

The assessment of the effects of radiological malfunctions and accidents focused on the two events during DSC on-site transfer and during DSC storage that have the potential to release radioactivity into the environment. The assessment of the effects of the release of tritium and krypton-85 following the bounding accident is based on releases of 1.4 x 1012 Bq of tritium and 7.8 x 1012 Bq of krypton-85 and is evaluated in a conservative manner.

Likely Environmental Effects
Non-Human Biota
The estimated dose from tritium and krypton-85 released following a bounding accident was calculated to be 0.0094 Gy which is less than 1% of the no-effect level (1 Gy) reported by UNSCEAR (1996).

Members of the Public and PN Non-NEWs
A preliminary estimate of the dose to members of the public at the PN property boundary was conservatively calculated at 1 µSv, based on PWMF I Safety Report methodology assumptions. This is a small fraction (0.1%) of the regulatory limit on annual dose to members of the public (Canada Gazette 2000). The estimated dose is below the level of regulatory concern as recommended by the ACRP/ACNS (1988), and the OPG dose target for malfunctions and accidents (i.e., that radiation doses to the public at the PN site boundary, following a postulated abnormal event or credible accident shall not exceed the annual public dose limit of 1,000 µSv). Also, the baseline annual dose to members of the public from licensed activities at the PN site is approximately 7 µSv/y, and from natural background radiation is approximately 1,300 µSv/y.

PWMF II Workers (NEWs)
The dose to workers at the PWMF II from the bounding malfunction and accident was estimated to be < 6 mSv, based on PWMF I Safety Report methodology assumptions. As discussed previously, the assumptions stated for the accident scenario are very conservative and extremely unlikely to occur. Nevertheless, if the bounding accident was postulated to occur near the end of a dosimetry year, the estimated dose to a worker at PWMF II could be in addition to a typical annual dose of approximately 0.64 mSv/y from normal operation. The total postulated dose for the year would be approximately 7 mSv, less than OPG's ECL of 10 mSv/y and a small fraction of the regulatory limit of 50 mSv in a calendar year, to a maximum of 100 mSv over a five-year period.

PN Workers (NEWs)
The dose to a worker at PN in proximity to a malfunction or accident is expected to be equal to or less than the corresponding dose to a PWMF II worker, i.e., 6 mSv as discussed above.

The individual dose to workers at PN from the bounding accident and malfunction would be in addition to the baseline dose received (average of 1.1 mSv/y). All internal and external doses received by workers at PN are monitored and are reported as part of their cumulative annual dose. If the accident was postulated to occur at the end of a dosimetry year, the average individual dose to a worker at PN is expected to be less than 7 mSv in that year, a small fraction of the regulatory limit. In some years, the annual dose to a few PN workers may approach the ECL of 10 mSv. If one of these workers were assumed to be exposed to the bounding malfunction or accident near the end of a dosimetry year, the total dose in the year could approach 16 mSv. This maximum postulated dose to a worker is also below the regulatory limit of 50 mSv in a calendar year, to a maximum of 100 mSv over a five-year period.

Identified Mitigation Measures
Radiation doses to workers and the public from radiological malfunctions and accidents are expected to be below CNSC's regulatory limits and OPG's ECLs. Also, radiation doses to nonhuman biota are expected to be below no-effects levels reported by UNSCEAR. Therefore, no mitigation measures are required.

9.4.3.2 Other Projects and Activities

PWMF I

The dose rate at the PN east property boundary from PWMF I operations has been estimated at 6 x 10-5 µSv/h (OPG 2002d), or a dose of 0.05 µSv/y to a member of the public assuming full occupancy at this location. This is a very small fraction of the CNSC regulatory limit of 1,000 µSv/y and is well below the level of concern recommended by the ACRP/ACNS.

9.5.1 Members of the Public

9.5.1.2 Identified Mitigation Measures

The estimated cumulative doses to the most exposed members of the public are expected to be small fractions of the CNSC regulatory limits; therefore, no mitigation measures are warranted.

9.5.2 Workers on the PN Property

9.5.2.1 Dose Levels

PWMF II Workers (NEWs)

In conclusion, cumulative radiation doses to PWMF II workers will be carefully controlled and monitored to ensure that OPG's ECL (< 10 mSv/y), which is well below regulatory dose limits, will not be exceeded.

PN Workers (NEWs and Non-NEWs)

In conclusion, cumulative radiation doses to PN workers will be carefully controlled and monitored to ensure that OPG's ECLs (< 1000 µSv/y to non-NEWs, and < 10 mSv/y to NEWs), which are below regulatory dose limits, will not be exceeded

9.5.2.2 Identified Mitigation Measures

The estimated cumulative dose to NEWs at the PWMF II and NEWs and non-NEWs at the PN, are expected to be less than CNSC regulatory limits; therefore, no mitigation measures are warranted or required.

9.5.3 Cumulative Dose to Non-Human Biota

The estimated cumulative dose to non-human biota is a small fraction (i.e., 5%) of the no-effects level (1 mGy/d) reported by UNSCEAR (1996) and is less than the corresponding values recommended by CNSC staff in a paper presented at the 2002 Conference on Ecological Risk Assessment in Australia (Bird et al. 2002)

9.5.3.2 Identified Mitigation Measures

The estimated cumulative dose to non-human biota is expected to be less than the no-effects levels reported by UNCSEAR; therefore, no mitigation measures are warranted or required.

SOURCE: Refurbishment and Continued Operation of Pickering B Nuclear Generating Station Environmental Assessment. December 2007. NK30-REP-07701-00002

5.9.2.3 Evaluation of Effects for Continued Operation

The predicted gamma radiation levels from full Storage Buildings provides a dose rate of ≤ 10 μSv/y at the PN property boundary, based on full occupancy 100% of the year. This includes both direct and skyshine contributions. The effect of gamma radiation on the terrestrial environment at the PN property boundary from the Storage Buildings is expected to be ≤ 10μSv/y. This effect will be indistinguishable from the temporal and spatial variations in natural background radiation levels at this location.

A dose rate of 50 μSv/h was predicted on the roof of the DSC Storage Buildings from an array of loaded DSCs completely filling the buildings. Nesting of birds on the roofs of storage buildings at PWMF I and PWMF II is discouraged by the very nature of the roof design. However, birds may perch on the roof of the Storage Buildings for brief periods, and be exposed to (absorbed) dose rates of approximately 0.05 mGy/h from gamma radiation. Exposure periods of one or two hours per day would result in dose rates of up to 0.1 mGy/d. This dose rate is less than the no effects level of 1 mGy/d reported by UNSCEAR (1996).

The gamma radiation levels from loaded DSCs in PWMF II Storage Buildings are predicted to produce a dose rate less than 0.5 μSv/h at the perimeter fence of the PWMF II site. Therefore, the corresponding absorbed dose rates to flora and fauna were estimated at 0.0005 mGy/h. The estimated daily dose rate to flora and fauna at the perimeter of the PWMF II site is approximately 0.012 mGy/d, and is a small fraction of the no-effects level of 1 mGy/d reported by UNSCEAR (1996). Also, the predicted dose rate is expected to be within the range of natural background, which is 0.004 to 0.02 mGy/d.

5.9.2.4 Identified Mitigation Measures

Similar to the Refurbishment Phase, the storage of the refurbishment waste is expected to have locally elevated gamma radiation levels which are predicted to be less than 0.5 µSv/h. This dose rate was established by OPG to ensure that even for 2000 h/y occupancy, the dose to a human would not exceed 1 mSv. In addition, however, a dose rate of 0.5 µSv/h is far below any relevant dose-rate criteria for non-human biota. Moreover, these levels are within the range of levels previously experienced at the PN site. Therefore, with the access to these storage areas closely controlled, there is no additional mitigation needed.

5.9.5.3 Evaluation of Effects for Continued Operation

The annual doses to individual NEWs during normal operation are well below the regulatory limits, a maximum of 50 mSv in a one-year dosimetry period and an average of 20 mSv in a one year dosimetry period (i.e., a cumulative dose of 100 mSv in five one-year dosimetry periods). In addition, doses will be controlled to ALARA using internal dose control limits, such as the ADL and ECL.

Doses to NEWs due to continued operation of the waste management facility will be the same as encountered presently at the PWMF (i.e., an average individual dose of approximately 0.64 mSv per year per worker). After completing the placement of the refurbishment waste into storage, there will only be maintenance and caretaking activities inside the storage buildings, and thus, future doses to workers at PWMF are expected to be comparable to existing doses.

5.9.5.4 Identified Mitigation Measures

Radiation doses to NEWs in the Regional and Local Study Areas from the Continued Operation of PNGS B following refurbishment are expected to be indistinguishable from the baseline doses from the PNGS in the Regional and Local Study Areas. Furthermore, the Continued Operation of PNGS B following refurbishment is expected to result in radiation doses to NEWs in the Site Study Area that are well below the corresponding regulatory limits, and within OPG dose targets and ECLs.

As no distinguishable changes in dose levels from baseline conditions are expected during refurbishment or continued operation, additional mitigation measures are not required.

5.9.6.3 Evaluation of Effects for Continued Operation

As mentioned previously, the access and movement of visitors and non-NEW workers on the PN site is controlled by OPG, and the radiation doses to these individuals from licensed activities on the PNGS site are controlled by OPG to ensure that they do not exceed 1 mSv/y, the regulatory limit on annual dose to non-NEWs (Canada Gazette 2000). At the perimeter fence of the PWMF II site, the dose rate is predicted to be less than 0.5 µSv/h which corresponds to a dose rate of < 1,000 µSv/y for 2,000 h/y occupancy, the CNSC public dose limit for non-NEWs (Canada Gazette 2000). It is highly unlikely that a non-NEW would spend appreciable time in this area and thus, the doses to non-NEWs are expected to be well below the CNSC public dose limit. Therefore, the radiation doses to non-NEWs from the continued operation are expected to be indistinguishable from the radiation doses from normal operation of the reactors and well below the regulatory limit of 1 mSv/y for non-NEWs.

5.9.6.4 Identified Mitigation Measures

Radiation doses to members of the public in the Regional and Local Study Areas from the continued operation of PNGS B following the refurbishment are expected to be indistinguishable from the baseline doses from the PNGS in the Regional and Local Study Areas. Furthermore, the continued operation following refurbishment is expected to result in radiation doses to visitors and non-NEW workers on the PN site (i.e., in the Site Study Area) that are less than the corresponding regulatory limit for members of the public of 1 mSv/y (Canada Gazette 2000). As no distinguishable changes in dose levels from baseline conditions are expected during refurbishment or continued operation, additional mitigation measures are not required.

Section A6

Description from Record of Proceedings and Record of Decision:

SOURCE: Record of Proceedings, Including Reasons for Decision. May 28, 2004.
Subject: Environmental Assessment Screening Report on the proposed expansion of the Pickering Waste Management Facility (Phase II)

4. Conclusion

The Commission concludes that the environmental assessment Screening Report attached to CMD 04-H7 (as amended) is complete and meets all of the applicable requirements of the Canadian Environmental Assessment Act.

The Commission concludes that the project, taking into account the appropriate mitigation measures identified in the Screening Report, is not likely to cause significant adverse environmental effects.

SOURCE: Record of Proceedings, Including Reasons for Decision. December 10, 2008.
Subject: Screening Environmental Assessment of the Pickering Nuclear Generating Station B Refurbishment and Continued Operations Project, Pickering, Ontario

17. The Commission reviewed the EA Screening Report and concluded that it is complete and in accordance with the requirements of the CEAA.

57. Based on its review of the Screening Report and the above-noted information provided on the record, the Commission concludes that the proposed project, taking into account the mitigation measures, described in section 8 of the EA Screening Report, is not likely to cause significant adverse effects to the environment.

107. To address concerns raised by several intervenors on waste management, the Commission requested that OPG elaborates on the design of the dry-storage container used for used fuel storage and on the fuel cycle after the removal of fuel from the reactor. OPG responded that the dry-storage container was a very robust container consisting of a 13mm-thick steel inner liner and a 13mm-thick steel outer liner with approximately half a metre of high-density reinforced concrete between those two liners. OPG added that the containers, without fuel, weigh approximately 70 tonnes and that they were extremely robust and very similar to those used elsewhere in North America and around the world. OPG noted that they had proven to be adequate for storing spent nuclear fuel for extended periods of time as long as fifty years. To answer the fuel cycle portion of the question, OPG added that the fuel removed from the reactor is stored in water pools at the stations for a minimum of 10 years to allow the fuel to cool to about 0.1 % of the radioactivity levels present at the time of its removal from the reactor. The fuel is then transferred to dry-storage containers for storage until a disposal facility is available.

SOURCE: Record of Decision. April 13, 2017.
Subject: Application to Renew the Waste Facility Operating Licence for the Pickering Waste Management Facility

110. Based on the information considered for this hearing, the Commission is satisfied that the ALARA concept is adequately applied to all PWMF activities.

113. CNSC staff informed the Commission that, in keeping with the ALARA principle, OPG had planned improvements to its radiation protection program during the proposed renewed licence period and CNSC staff would be closely monitoring these initiatives.
115. Based on the information provided for this hearing, the Commission is satisfied that doses to workers at the PWMF are adequately controlled.

121. Based on the information provided on the record for this hearing, the Commission concludes that, given the mitigation measures and safety programs that are in place and will be in place to control radiation hazards, OPG provides, and will continue to provide, adequate protection to the health and safety of persons and the environment throughout the proposed renewed licence period.

122. The Commission is satisfied that OPG's radiation protection program at the PWMF meets the requirements of the Radiation Protection Regulations.

131. The Commission concludes that the health and safety of workers and the public was adequately protected during the operation of the facility for the current licence period and that the health and safety of persons would also be adequately protected during the continued operation of the facility in the proposed renewed licence period.

157. Based on the information submitted by CNSC staff in the EA Report, the Commission is satisfied that the EA adequately shows that OPG made and will continue to make adequate provision for the protection of the environment and persons at the PWMF site.

158. The Commission is satisfied that OPG's and the CNSC's environmental monitoring show that the public and the environment around the PWMF site remain protected.

166. Based on the information presented on the record for this hearing, the Commission is satisfied that the ERAs were carried out satisfactorily and showed that OPG was adequately protecting the environment in the vicinity of the Pickering NGS, and therefore, the PWMF site.

168. Based on the assessment of the application and the information provided on the record at the hearing, the Commission is satisfied that, given the mitigation measures and safety programs that are in place to control hazards, OPG will provide adequate protection to the health and safety of persons and the environment throughout the proposed licence period.

218. Based on the information presented on the record for this hearing, the Commission is satisfied that OPG is meeting, and will continue to meet, regulatory requirements regarding packaging and transport.

Enclosure 2 to OPG Letter, K. Aggarwal to D. Saumure, “OPG – Change Request Application for Amendment to the Pickering Waste Management Facility (PWMF) Waste Facility Operating Licence W4-350.00/2028,”
CD# 92896-CORR-00531-01478

ENCLOSURE #2

OPG report
“Safety Assessment Storing Lower Aged Fuel in PWMF SB3”
92896-REP-01320-00012

ONTARIO POWER GENERATION

Report

OPG Proprietary	
Document Number: **92896-REP-01320-00012**	Usage Classification: **N/A**
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Title:
SAFETY ASSESSMENT STORING LOWER AGED FUEL IN PWMF SB3

Safety Assessment Storing Lower Aged Fuel in PWMF SB3

92896-REP-01320-00012 R000
2020-06-30

Order Number: N/A
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Table of Contents

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Revision Summary

Revision Number	Date	Comments
R000	2020-06-30	Initial issue.

1.0 INTRODUCTION

The Pickering Waste Management Facility (PWMF) Used Fuel Dry Storage (UFDS) area consists of a processing workshop for preparing the Dry Storage Containers (DSCs) loaded with used fuel bundles for storage and three storage buildings (SB1 and SB2 at the Phase I site location and SB3 at the Phase II site location) for storing the DSCs. SB4 is currently being constructed at the Phase II site.

The existing operation of the PWMF involves the processing and storage of DSCs containing used fuel with a minimum of ten (10) years of decay. In order to support PWMF operations, an analysis to determine the impacts of loading used fuel cooled for less than ten (10) years is being completed. These lower-fuel-age DSCs are planned to be stored in SB3.

The existing PWMF Safety Report [1] has considered the storage of DSCs containing used fuel with a minimum of ten (10) years decay for normal operations and malfunctions/accidents. As such, a safety assessment is required to determine if storing fuel that has been out of the core for a period of less than ten (10) years is acceptable from a nuclear safety point of view.

The objective of the current safety assessment is to incorporate the transfer, handling, and storage of DSCs containing used fuel that has only cooled for six (6) years[1] during normal operations and for malfunctions/accident conditions based on the SB4 safety assessment [2]. In addition to the existing hazards identified in Reference [2], potential hazards associated with the transfer of the lower-fuel-age DSCs from the station for processing, re-arrangement and/or removal of a number of the existing DSCs in order to place the lower-fuel-age containers to their storage location in SB3 are included in the assessment.

2.0 SCOPE

This report documents the safety assessment for the processing, transfer, handling, and storage in SB3 of up to 100 DSCs[2] containing 6 year decayed used fuel as well as the re-arrangement and removal of a number of the existing DSCs[3] to accommodate the incoming lower-fuel-age DSCs. The safety assessment for the lower-fuel-age DSCs as well as any impact on the whole-site events, such as earthquakes, floods and tornadoes are included herein.

In addition, a qualitative discussion is provided in Section 5.5 of this report on the fuel sheath temperature for 6 year decayed used fuel.

3.0 QUALITY ASSURANCE

The Project activities will be performed by Candu Energy Inc. in accordance with the Quality Assurance (QA) program described in 147-912020-QAP-001 “CANDU Services Projects (CSA Z299 Series)”, CE-912020-QAM-002 “Candu Energy Inc. – Quality Assurance Manual” and

1 A cooling period of six (6) years represents the conservative limit for the fuel age to be stored in the DSCs.
2 100 DSCs represents the conservative limit for the number of DSCs to be replaced in SB3.
3 The loading pattern of DSCs in SB3 is proposed to ensure the DSCs containing 6 year decayed used fuel are surrounded by DSCs containing used fuel decayed for longer periods with the intention of minimizing dose rates external to the building. In addition, because DSCs are being transferred out of SB3 to SB4 (e.g. to make room in SB3 to allow younger fuel to be stored), older DSCs will be selected for the transfer into SB4 due to their lower dose rates.

CE-912020-QAM-003 “Quality Assurance Manual – Analytical, Scientific and Design Computer Programs” to satisfy the QA requirements of the following standards applicable to the Project scope of work:

- CSA CAN3-Z299.1-85 “Quality Assurance Program Category 1”;
- CSA N286-12 “Management System Requirements for Nuclear Facilities”; and
- CSA N286.7-16 “Quality Assurance of Analytical, Scientific and Design Computer Programs for Nuclear Power Plants”.

4.0 DSC STORAGE DESCRIPTION

The PWMF site has undergone an orderly development in phases to facilitate the growing number of DSCs over the years. These phases are:

- Phase I: The PWMF Phase I site is located within the Pickering Nuclear Generating Station (PNGS) protected area, southeast of PNGS Unit 8, adjacent to the east side of the station security fence. The Phase I site consists of a DSC Processing Building (PB), SB1 and SB2, and the Retube Components Storage (RCS) area.
- Phase II: The PWMF Phase II site is located approximately 500 m northeast of the PWMF Phase I site, east of the PNGS powerhouse, within its own protected area in the Pickering Nuclear site. The Phase II site consists of SB3 with provision for future DSC SB 4.

The existing facilities within the PWMF, including the RCS area, a PB, and the three DSC storage buildings (SB1, SB2, and SB3), are shown in Figure 4-1 and Figure 4-2. The future SB4 is being constructed to the south of SB3 and is shown in Figure 4-3.

The DSC preparation process is shown in Figure 4-4 and the DSC storage arrangement is shown in Figure 4-5, similar to the storage arrangement at the existing storage buildings.

A general description of the used fuel stored in DSCs is provided in Table 4-1.

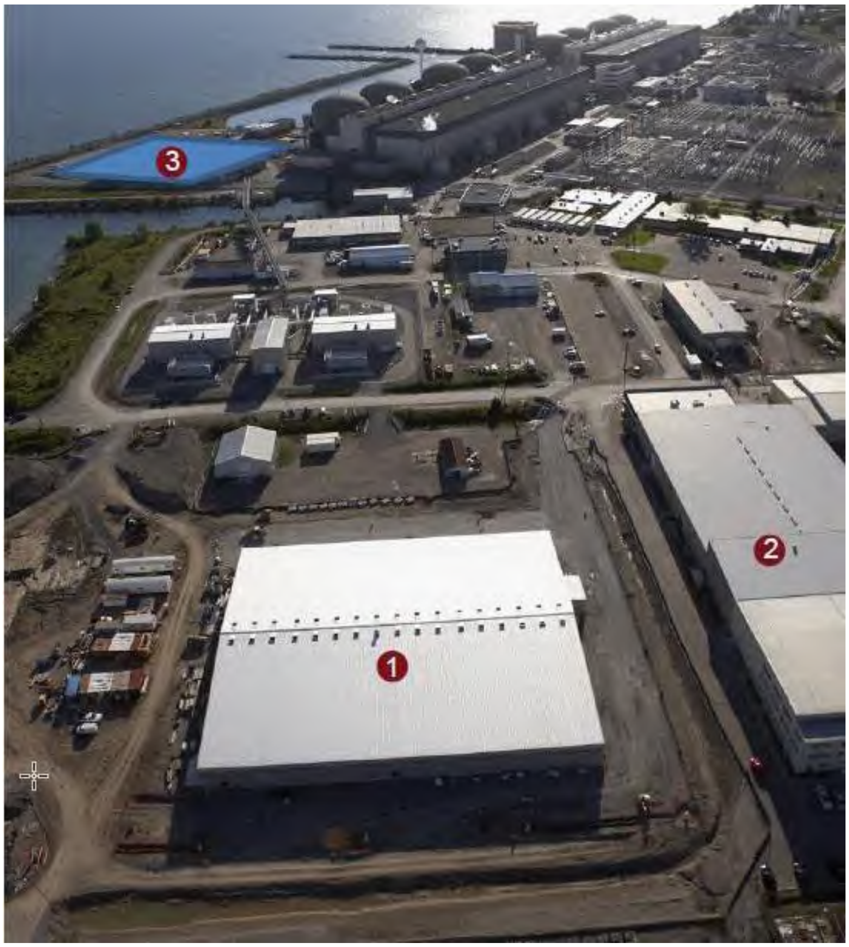
Table 4-1: Summary of Used Fuel Storage in DSCs at PWMF

Parameter	Unit	Value
Fuel bundles per DSC	-	384
Number fuel elements per bundle	-	28
Bundle length	mm	495
Mass of UO_2	kg	22.87
Mass of Zircaloy	kg	1.67
Mass of U	kg	20.16
Mass of bundle	kg	24.54
Bundle fission power	kW	373
Burnup	MWh/kgU	230
Fuel decay age	year	≥6

❶ Pickering A Re-tube Components ❷ DSC Processing ❸ DSC Storage Building 1
❹ DSC Storage Building 2 ❺ Pickering B Station

Figure 4-1: Aerial View of PWMF Phase I

From Figure 2.1 of Reference [1]



1 DSC Storage Building 3
2 East Warehouse Complex
3 PWMF – Phase 1

Figure 4-2: Aerial View of PWMF Phase II

From Figure 2.2 of Reference [1]

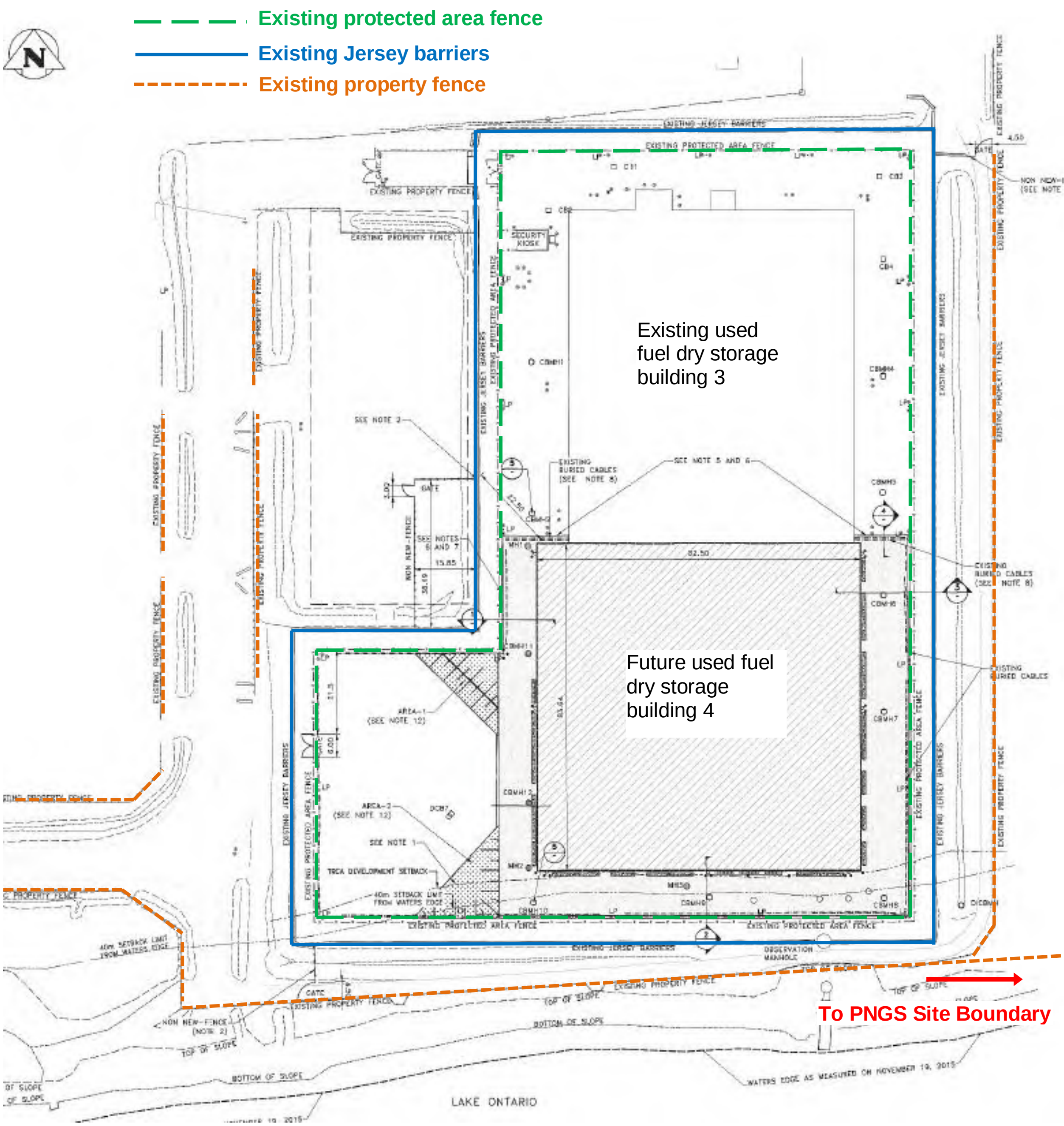


Figure 4-3: General Layout of SB3 and SB4

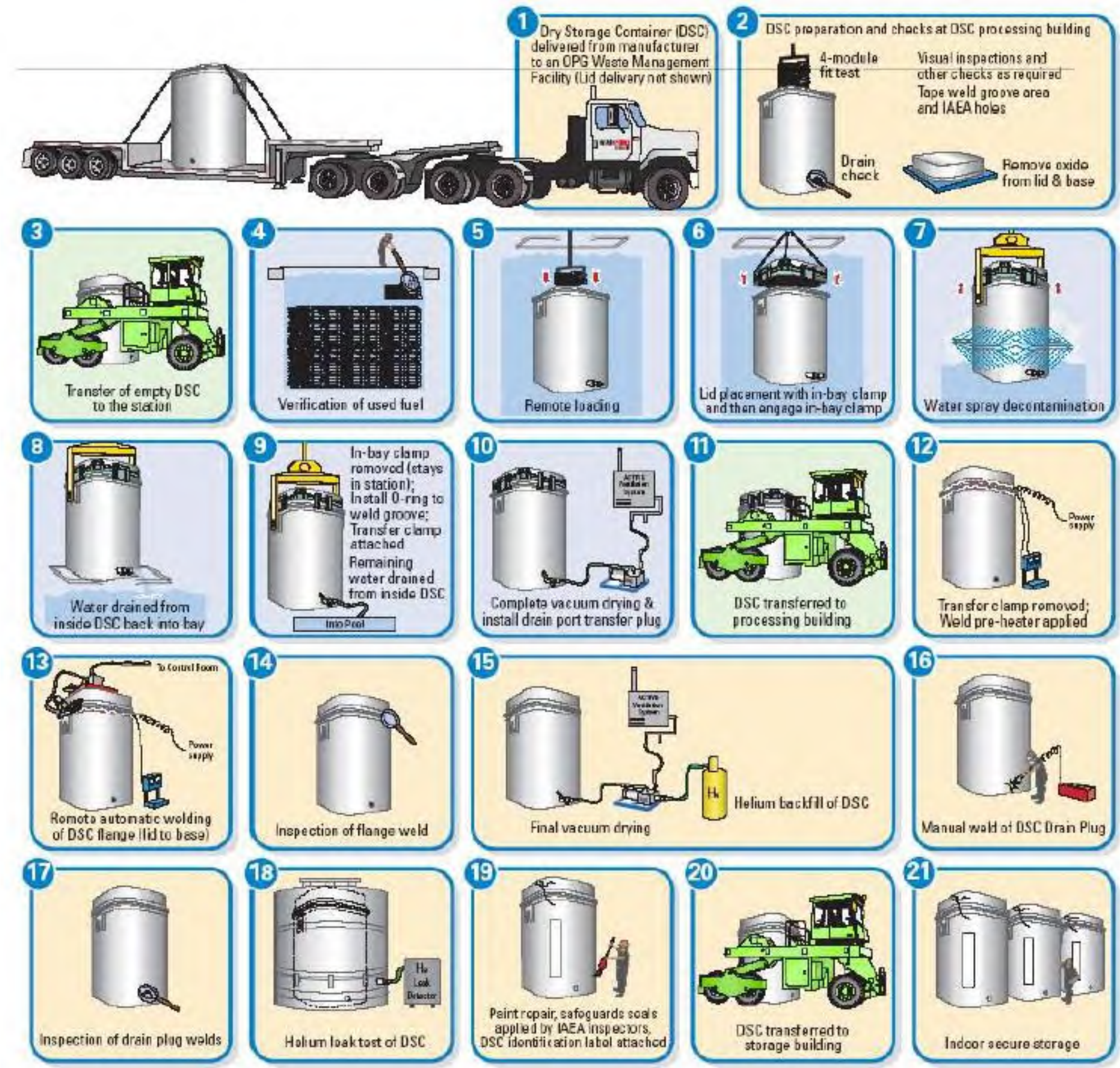


Figure 4-4: Used Fuel Dry Storage Process

From Figure 3-1 of Reference [3]

Figure 4-5: Typical DSC Storage at PWMF

From Figure 2.3 of Reference [1]

5.0 SAFETY ASSESSMENT OF DSC STORAGE IN SB3

5.1 Safety Assessment Approach

Under normal operating conditions, storage containers, buildings, and structures at the PWMF are expected to provide reasonable assurance that the radioactive waste can be stored and retrieved without undue radiological risk to workers, members of the general public, or the environment. Waste operations comply with OPG requirements to keep total radioactive emissions under normal operating conditions below regulatory limits and As Low As Reasonably Achievable (ALARA).

The safety assessment of normal and abnormal operating conditions and credible accident conditions is discussed below. In many cases, the scenarios represent bounding abnormal or postulated accident conditions that are improbable or highly unlikely to occur. Design provisions and procedural measures have been introduced as necessary to prevent, mitigate and accommodate the assessed consequences of these conditions.

Guidance documented in the CSA N292.0-14 [4], CSA N288.1-14 [5], and CSA N288.2-14 [6] standards was used in performing the safety assessment.

5.2 Acceptance Criteria

The radiation safety requirements for the PWMF under normal operation[4] are the following:

- <10 µSv per year for a member of the general public at or beyond the PNGS site boundary. This dose rate target is one percent (1%) of the CNSC regulatory dose limit [7] of 1 mSv per year for a member of the public [1].
- <0.5 µSv/h at the fence (boundary of the PWMF licensed facility), based on the 1 mSv/a effective dose limit for non-Nuclear Energy Workers (non-NEWs) and a maximum occupancy of 2000 hours per year [1].
- The effective dose limit for NEWs is 50 mSv/a in a one-year dosimetry period and 100 mSv in a five-year dosimetry period [1].

The radiation safety requirements following malfunctions or accident conditions are given below[5]:

- The dose acceptance criterion for members of the public at or beyond the site boundary for a period of 30 days[6] [6] after the analyzed event shall be less than 1 mSv [1].
- The dose acceptance criterion for NEWs following malfunctions or credible accident conditions shall be less than 50 mSv [1].

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4 As per Section 4.2 of Reference [1], these requirements are for the operation of the PWMF only and are exclusive of the dose from the PNGS. Additional discussion on the radiation safety requirements and dose rate targets is provided in Reference [1].

5 The 1 mSv public dose acceptance criterion follows the prescribed limit to the general public given in the Radiation Protection Regulations [7].
The worker dose acceptance criterion follows the maximum annual dose to NEW given the Radiation Protection Regulations [7].

6 The 30-day period of exposure follows the recommendation given in the CSA N288.2-14 Section 7.8.2.2 “For demonstration of compliance with regulatory limits, a period of residence of 30 days over contaminated ground shall be used”. This is a departure from the approach used in the existing PWMF Safety Report [1] in which considers the duration of the plume release as the exposure duration.

5.2.1 ALARA – Worker Dose Management Target

The ALARA dose target for an individual PWMF worker is 3 mSv per year [1].

5.3 Normal Operating Conditions

5.3.1 Radioactive Emissions

Chronic releases of radionuclides from the normal operation of the PWMF are measured and reported in PWMF quarterly reports[7]. Reported data include survey results from the retube component storage facility, used fuel dry storage facility stack samples, and active liquid waste tank samples. Almost all of the weekly measured values from the used fuel dry storage facility stack sampler particulate sample were below the minimum detectable activity of 3.3×10^{3} Bq[8]. Following the approach outlined in the PWMF Safety Assessment Update for the purpose of estimating the normal operation releases, weekly measurement values that were below the minimum detectable activity are set to 3.3×10^{3} Bq and the particulate release is represented by cobalt-60 release [3]. The annual particulate releases are listed in Table 5-1.

Detailed discussion on sources of radioactive emissions is provided in the Reference [3]. The storage of 100 DSCs containing 6 year decayed used fuel in SB3 is not expected to introduce detectable radioactive emissions during normal operating conditions of the PWMF because DSCs being transferred and stored will not contain fuel known to be damaged. While no significant releases are expected from DSCs under normal operating conditions, small quantities of fixed surface contamination may become airborne during welding operations [1].

Table 5-1: Annual Particulate Releases from PWMF Stack Sampler

Year	Bq/a release
2007	1.72×10^{5}
2008	1.92×10^{5}
2009	2.00×10^{5}
2010	1.85×10^{5}
2011	1.72×10^{5}
2012	1.72×10^{5}
2013	1.72×10^{5}
2014	1.79×10^{5}
2015	1.85×10^{5}
2016	1.72×10^{5}
2017	1.72×10^{5}
2018	1.72×10^{5}
2019	1.75×10^{5}

7 Quarterly reports are available from the 92896-REP-00531-* series of reports.
8 The minimum detectable activity is provided in the PWMF quarterly reports.

5.3.1.1 Postulated Chronic Release from DSC Processing

The 100 DSCs containing 6 year decayed used fuel to be stored in SB3 follow the same preparation process as existing DSCs. However, the postulated chronic release from DSC processing in the latest safety assessment update [3] is based on DSCs containing 10 year decayed used fuel. The radioactive inventory available for release from the used fuel within the DSC is dependent on both the burnup and the decay age of the used fuel. As no emissions for noble gases, carbon-14, or tritium were available, following the methodology presented in Reference [3] the postulated chronic releases from processing of DSCs containing 6 year decayed used fuel (of 230 MWh/kgU burnup) are as follows:

Radionuclide	Annual Release from DSCs Containing 6 Year Decayed Used Fuel (Bq/a)	Annual Release from DSCs Containing 10 Year Decayed Used Fuel [3] (Bq/a)
Kr-85	3.09×10^{11}	2.38×10^{11}
Tritium (HTO)	5.00×10^{10}	4.32×10^{10}
C-14	4.10×10^{6}	4.91×10^{6}

Notes:
- The Bq/a release values for 6 year decayed used fuel were derived from the radionuclide inventory of a 6 year decayed used fuel bundle (bundle radionuclide inventory presented in Appendix A).
- The Bq/a release values for 10 year decayed used fuel were calculated as part of work document in Reference [3] based on a bundle-wise calculation. The fuel bundle radionuclide inventory has since been revised using a ring-wise calculation, resulting in a decrease of C-14 (see the discussion provided in Appendix A).
- The Bq/a release values were calculated based on releases from 280 failed fuel elements (i.e. 4 failed fuel elements per DSC and 70 DSCs being processed each year).
- For H-3 and Kr-85, the release fraction for the failed fuel element is 0.0218, which is f_{gap} + 10% f_{gb}:
  - f_{gap} = fraction of gap inventory = 0.0095
  - f_{gb} = fraction of grain boundary inventory = 0.123
- For C-14, the amount released to the gap and grain boundary is set to 0.1% [1].
- The Bq/a release values were calculated based on releases from 280 failed fuel elements (i.e. 4 failed fuel elements per DSC and 70 DSCs being processed each year).

The postulated chronic releases from processing of DSCs containing 10 year decayed used fuel (of 230 Mwh/kgU burnup) [3] are provided for comparison.

5.3.1.2 Postulated Chronic Release from DSMs

Dry Storage Modules (DSMs) at the PWMF are used to store legacy retube waste, including pressure tubes, end fittings, and shield plugs. Used fuel bundles are not stored in DSMs. Therefore, the releases from DSMs are expected to be the same as those documented in Reference [3]. For the purpose of evaluating the potential emissions from DSMs, the chronic release of carbon-14 is taken to be 1.6×10^{10} Bq per year [3].

5.3.2 External Gamma Dose Rates

5.3.2.1 Dose Rates from Single DSC

Calculated dose rates using Monte Carlo transport methodology documented in References [8], [9], and [10] have been demonstrated to be conservative compared with actual DSC dose rates measured during UFDS storage operations. For DSCs loaded with reference used fuel bundles (decayed by 10 years or older), the measured contact dose rates to date are in the range of 9 to 13 μSv/h [1]. This is about a factor of 4 conservative compared with the calculated estimate of the near contact (at the DSC long side) dose rate of 37.9±0.2 μSv/h for reference used fuel (decayed by 10 years). At 1 m distance, measured dose rates are about 5 to 7 μSv/h [1], compared with calculated dose rate estimates of 20.0±0.1 μSv/h.

The estimated dose rates from a DSC containing 6 years decayed used fuel are 97.4±2.6 μSv/h at near contact and 51.2±0.9 μSv/h at 1 m [9]. These dose rates are a factor of approximately 2.6 times larger than the dose rates calculated for used fuel decayed 10 years. Therefore, it is expected that the measured dose rates for DSCs containing 6 year decayed used fuel will increase by a similar factor (2.6x)[9] compared to the dose rates measured from the DSCs containing the reference used fuel[10]. The impact of the expected increase in measured dose rates on the dose to workers is discussed in Section 5.3.4.

The calculated dose rates from a DSC, fully loaded with Pickering 6 year decayed used fuel bundles (230 MWh/kgU burnup) are listed in Table 5-2 and Figure 5-1. The dose rates as a function of distance from the DSC and cooling time are tabulated in Table 5-3.

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9 The majority of this increase is driven by the greater amount of Rh-106 and Pr-144 in the 6 year decayed used fuel [9].

10 This is generally true if the energy spectra are the same. A check was performed which indicates that there is no significant difference in the average energy per energy group in the binning used in the dose rate calculation [9].

Table 5-2: Calculated Dose Rate (μSv/h) vs. Distance from a Single DSC Containing 6 Year Decayed Used Fuel [9]

Distance From Surface (cm)	Dose Rate (μSv/h)		
	Long Side	Short Side	Top
Near Contact[a]	97.4	86.2	70.5
50	77.4	62.7	49.8
100	51.2	42.9	n/a[b]
150	37.7	29.1	17.0
200	27.7	20.7	10.8
250	23.7	15.5	10.5
300	17.4	12.5	6.4
350	12.8	10.5	5.4
400	10.4	9.0	4.1
450	8.9	6.7	3.2
500	7.2	6.0	2.1

Notes:

a) Contact dose rates were calculated at a distance of 5 cm from the DSC surface.

b) The dose rate at 100 cm from the top of the DSC surface is excluded as the associated statistical uncertainty is larger than the 10% target presented in Section 3.10 of Reference [9].

Table 5-3: Calculated Dose Rate (μSv/h) vs. Distance from a Single DSC (Long Side) at Various Decay Times [9]

	Used Fuel Bundle Decay Time (year)								
Distance (cm)	**6 y**	**10 y**	**15 y**	**20 y**	**25 y**	**30 y**	**35 y**	**40 y**	**Maximum 1σ Uncertainty[b]**
Near Contact[a]	97.4	37.9	26.6	21.0	17.1	14.2	11.9	10.1	2.7%
50	77.4	29.0	20.3	16.0	13.0	10.8	9.1	7.7	2.7%
100	51.2	20.0	14.1	11.1	9.0	7.5	6.3	5.4	1.7%
150	37.7	14.4	10.1	7.9	6.4	5.3	4.5	3.8	2.6%
200	27.7	10.6	7.4	5.8	4.7	3.9	3.3	2.8	3.4%
250	23.7	8.3	5.7	4.5	3.7	3.0	2.6	2.2	9.7%
300	17.4	6.4	4.5	3.5	2.8	2.4	2.0	1.7	5.5%
350	12.8	5.1	3.6	2.8	2.3	1.9	1.6	1.4	2.8%
400	10.4	4.2	2.9	2.3	1.9	1.6	1.3	1.1	2.6%
450	8.9	3.5	2.4	1.9	1.6	1.3	1.1	0.9	4.8%
500	7.2	2.9	2.0	1.6	1.3	1.1	0.9	0.8	3.4%

Notes:
a) Contact dose rates were calculated at a distance of 5 cm from the DSC surface.
b) The uncertainty listed is the maximum uncertainty in the dose rate across all decay times for a given distance.

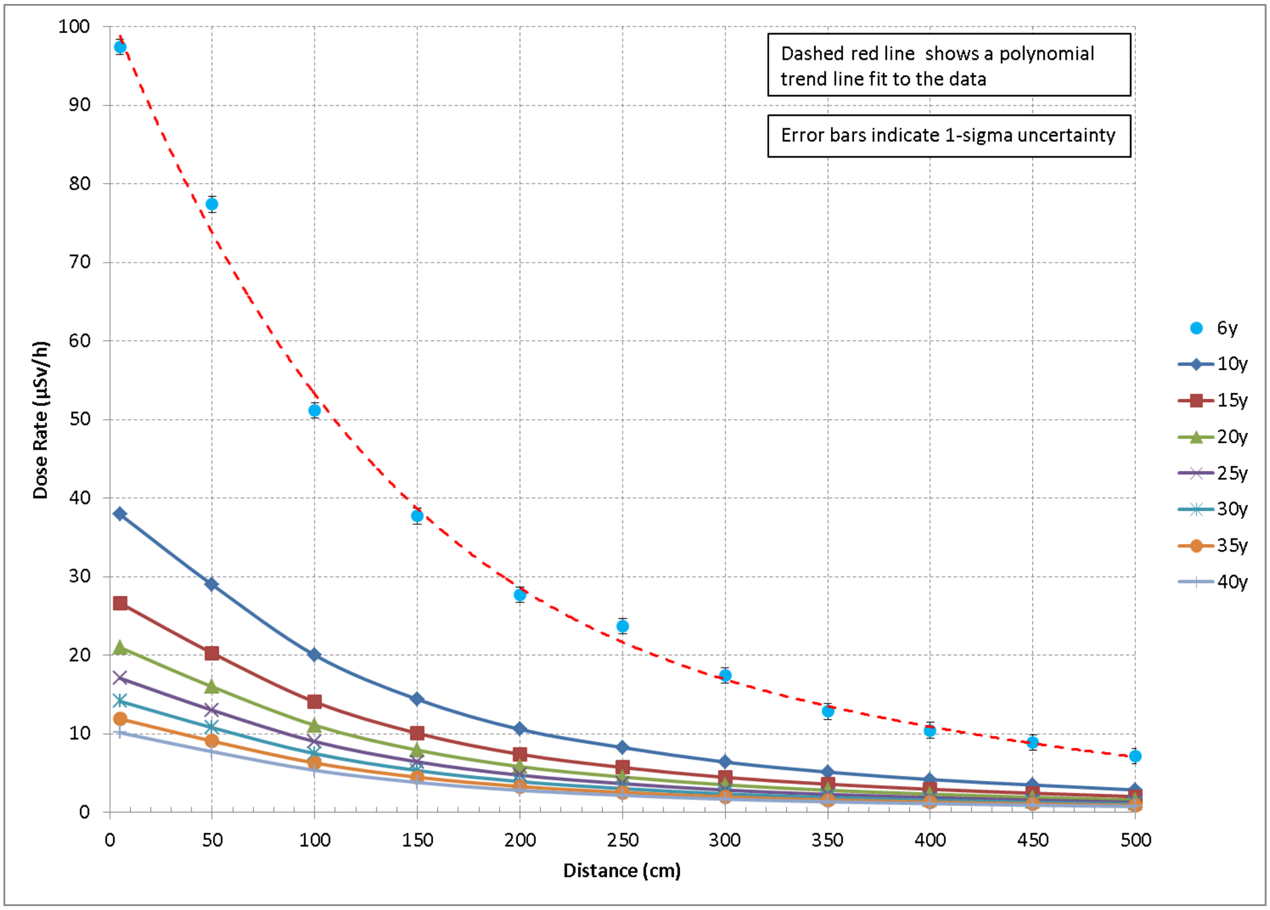


Figure 5-1: Calculated Dose Rate vs. Distance from the Long Side of a Single DSC at Various Fuel Decay Times [9][11]

[11] Note, the dose rate is estimated to drop below 0.5 µSv/h at approximately 7.5 m from the surface of the DSC containing 6 year decayed used fuel.

5.3.2.2 Dose Rates inside Storage Building 3

The occupational dose rate inside SB3 was estimated using the DSC layout shown in Figure 5-2 as part of the shielding assessment for DSCs containing 6 year decayed used fuel stored in SB3 [9]. The dose rate profile in the main aisle way of SB3 is shown in Figure 5-3. The maximum dose rate is estimated to be 13.6±0.5 µSv/h while the average dose rate in the main aisle way is estimated to be approximately 4.7±0.1 µSv/h.

These estimated dose rates across the SB3 main aisle way are significantly less than the maximum (33.9±1.6 µSv/h) and average (9.4±0.2 µSv/h) dose rates calculated for the SB4 main aisle way [10]. The difference in dose rates across the SB3 and SB4 aisles results from the different decay age used fuel stored in the two buildings. Compared to SB3, SB4 contains a larger portion of lower decay age used fuel (10 – 20 years) which contributes to a higher dose rate. Further, the loading pattern for SB4 has a larger amount of DSCs with low decay age fuel bordering the main aisle way which, as seen in Table 5-3, have larger dose rates than the 25 year decayed used fuel stored along the main aisle way in SB3

The proposed loading pattern of SB3 (see Figure 5-2) has the aisle way lined with DSCs containing 25 year decayed used fuel. When compared to the dose rates from a single DSC containing 6 year decayed used fuel, the calculated dose rates across the main aisle way are significantly lower. The DSCs containing the 25 year decayed used fuel lining the aisle way provide shielding from the DSCs with the lower fuel decay age.

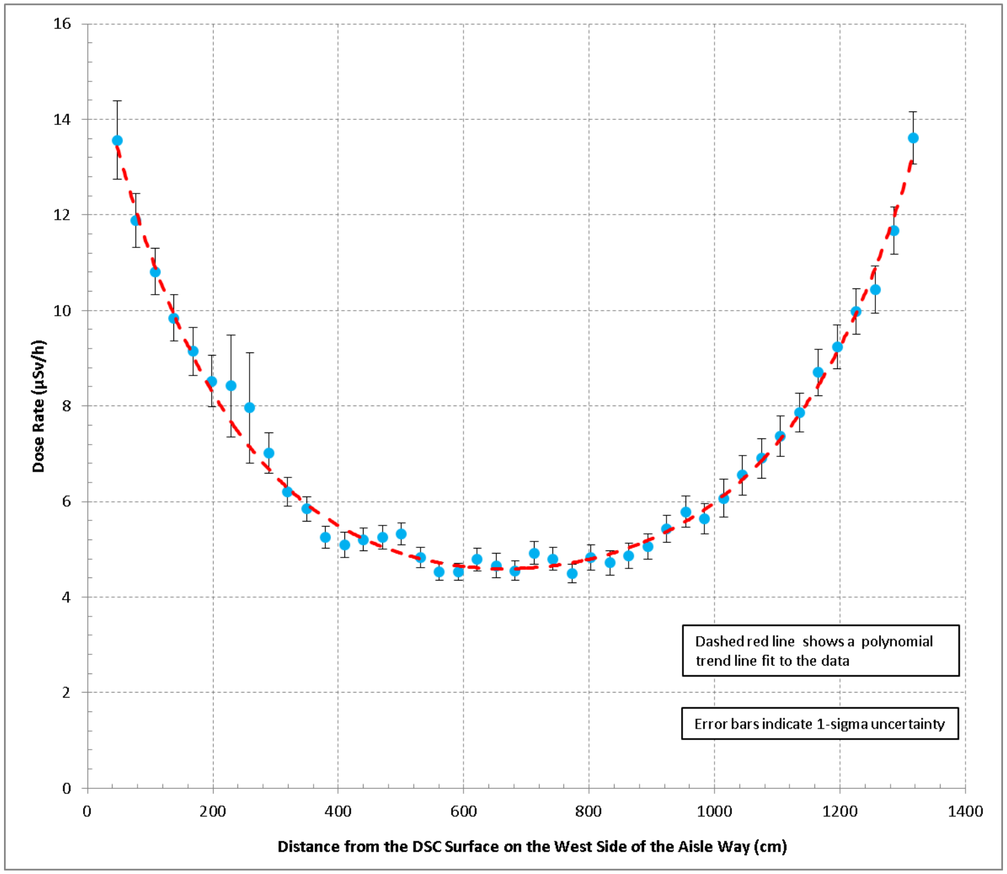
30	30	30	30	25	25	25	25	25	25
30	30	30	30	25	25	25	25	25	25
30	30	30	30	25	25	25	25	25	25
30	30	30	30	25	25	25	25	25	25
30	30	30	30	25	25	25	25	25	25
30	30	30	30	25	25	25	25	25	25
30	30	30	25	25	25	25	25	25	25
30	30	30	25	25	25	25	25	25	25
30	30	30	25	25	25	25	25	25	25
30	30	30	25	25	25	25	25	25	25
30	30	30	25	25	25	25	25	25	25
30	30	30	25	25	25	25	25	25	25
30	30	30	6	6	6	6	**25**	**25**	**25**
30	30	30	6	6	6	6	6	6	**25**
30	30	30	6	6	6	6	6	6	**25**
30	30	30	6	6	6	6	6	6	**25**
30	30	30	6	6	6	6	6	6	**25**
30	30	30	6	6	6	6	6	6	**25**
30	30	30	6	6	6	6	6	6	**25**
30	30	30	6	6	6	6	6	6	**25**
30	30	30	6	6	6	6	6	6	**25**
30	30	30	30	25	25	25	25	25	25
30	30	30	30	25	25	25	25	25	25
30	30	30	30	25	25	25	25	25	25

25	25	25	25	25	25	25	25	25	25
25	25	25	25	25	25	25	25	25	25
25	25	25	25	25	25	25	25	25	25
25	25	25	25	25	25	25	25	25	25
25	25	25	25	25	25	25	25	25	25
25	25	25	25	25	25	25	25	25	25
25	25	25	25	25	25	25	25	25	25
25	25	25	25	25	25	25	25	25	25
25	25	25	25	25	25	25	25	25	25
25	25	25	25	25	25	25	25	25	25
25	25	25	25	25	25	25	25	25	25
25	25	25	25	25	25	25	25	25	25
25	25	25	25	25	25	25	25	25	25
25	6	6	6	6	6	6	25	25	25
25	6	6	6	6	6	6	25	25	25
25	6	6	6	6	6	6	25	25	25
25	6	6	6	6	6	6	25	25	25
25	6	6	6	6	6	6	25	25	25
25	6	6	6	6	6	6	25	25	25
25	6	6	6	6	6	6	25	25	25
25	6	6	6	6	6	6	25	25	25
25	25	25	25	25	25	25	25	25	25
25	25	25	25	25	25	25	25	25	25
25	25	25	25	25	25	25	25	25	25

Values shown in the figure correspond to the DSC decay time in years

Figure 5-2: DSC Layout in SB3[12]

12 19 DSCs to be moved back to SB3, after loading the DSCs containing 6 year decayed used fuel, into locations indicated in bold.



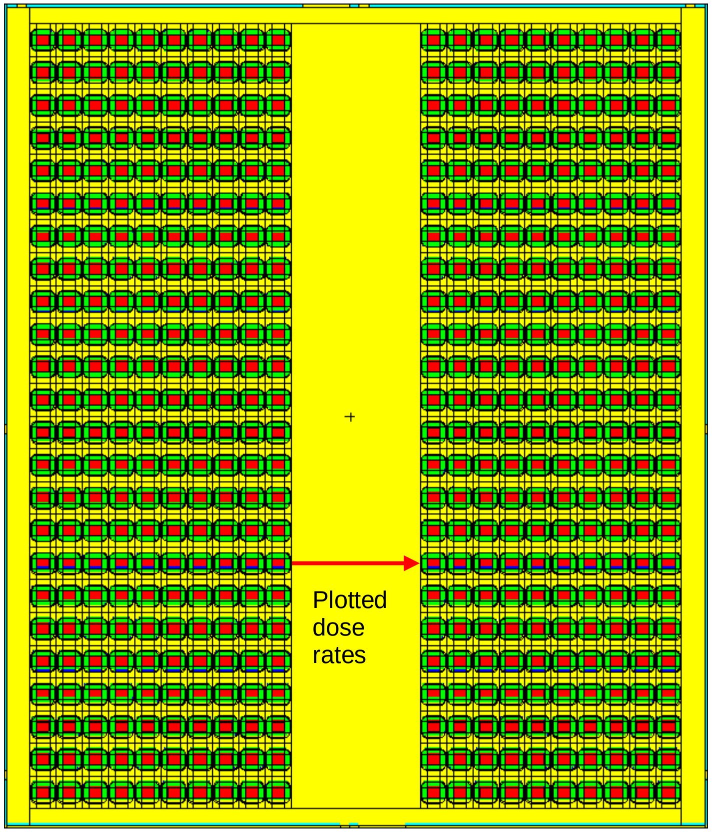


Figure 5-3: Dose Rates inside SB3

5.3.2.3 Dose Rates around PWMF

The limiting dose rates at the Pickering site boundary are calculated to be $(1.7\pm0.1)\times10^{-3}$ μSv/h (at the Montgomery Park Rd turnaround location) and $(1.6\pm0.1)\times10^{-3}$ μSv/h (lakeside exclusion zone boundary) [9]. The limiting dose rates are primarily from radiation sources from the existing SB3 and the DSCs to be stored in SB4. The contribution of radiation sources from DSCs and DSMs stored in the Phase I site to the direct external radiation field at the limiting locations around the Phase II site are negligible [11].

Dose rates at the existing protected area fence around SB3 and SB4 are expected to meet the 0.5 μSv/h dose rate criterion. However, calculations documented in Reference [9] suggest that dose rates at some sections of the fence could potentially be higher than the dose rate criterion (see Figure 5-4). It should be noted that the majority of the contribution to the dose rates at the fence locations that exceed 0.5 μSv/h are from DSCs stored in SB4, and not from the 6 year decayed used fuel DSCs stored in SB3. During the SB3 and SB4 operation, dose rates at the Phase II protected area fence will be measured and monitored and mitigating actions taken if required.

5.3.3 Public Dose

Contributors to the doses to members of the public during normal operation of the PWMF include the airborne radioactive emission and the external gamma dose rate from the radionuclides inside the DSCs and DSMs.

Dose to members of the public from emissions from normal operation of the PWMF have been determined based on the latest information on radionuclide emissions, representative group locations, and meteorological data [3]. The normalized annual doses resulting from the emission of radionuclides of interest are listed in Table 5-4 for releases from the Phase I site and Table 5-5 for releases from Phase II site. The dose receptor and critical group locations are shown in Figure 5-5. Locations included in the model are those identified by the Pickering site survey [12] and hypothetical locations along Pickering site exclusion zone boundary (see Figure 5-6). For landside hypothetical locations, receptors were assumed to be at their locations 100% of the time, i.e., 8760 hours per year. Receptors at the lakeside hypothetical locations were assumed to be present at that location 1000 hours per year.

Potential releases from normal operation of PWMF include chronic releases from DSCs during processing and chronic releases from existing DSMs. Both of these potential contributors to the normal operation releases are located in Phase I site. DSC storage in Phase II site is not expected to generate chronic releases during normal operation of the PWMF.

Hypothetical limiting public doses due to normal operations[13] of the PWMF calculated based on the radioactive emissions outlined in Section 5.3.1.1 are listed in Table 5-6. It is shown that hypothetical limiting public doses are significantly below the 1 mSv acceptance criterion outlined in Section 5.2. At the limiting landside and lakeside locations, the public doses are dominated by the external gamma radiation from DSCs described in Section 5.3.2.

[13] Considering 70 DSCs containing 6 year decay used fuel (of 230 MWh/kgU burnup) are processed in a year of operation of the PWMF and the releases outlined in Section 5.3.1.

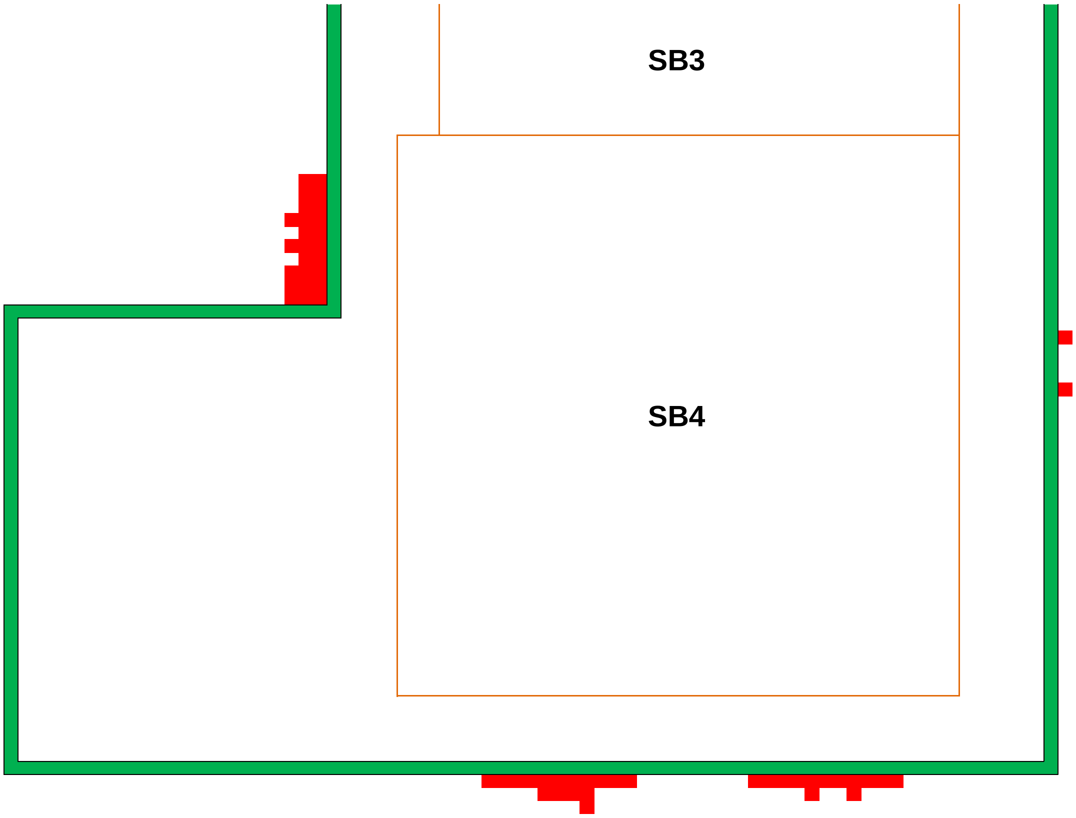


Figure 5-4: Representation of Dose Rates Exceeding Acceptance Criterion (red) Outside PWMF Phase II Protected Area Fence (green) [9][14]

14 Dose rates (best estimate + 2σ uncertainty) are compared against the 0.5 μSv/h acceptance criterion [9]. Each cell corresponds to a 2 m x 2 m x 2 m volume.

Table 5-4: Normalized Annual Doses from Chronic Releases at Phase I Site [3]

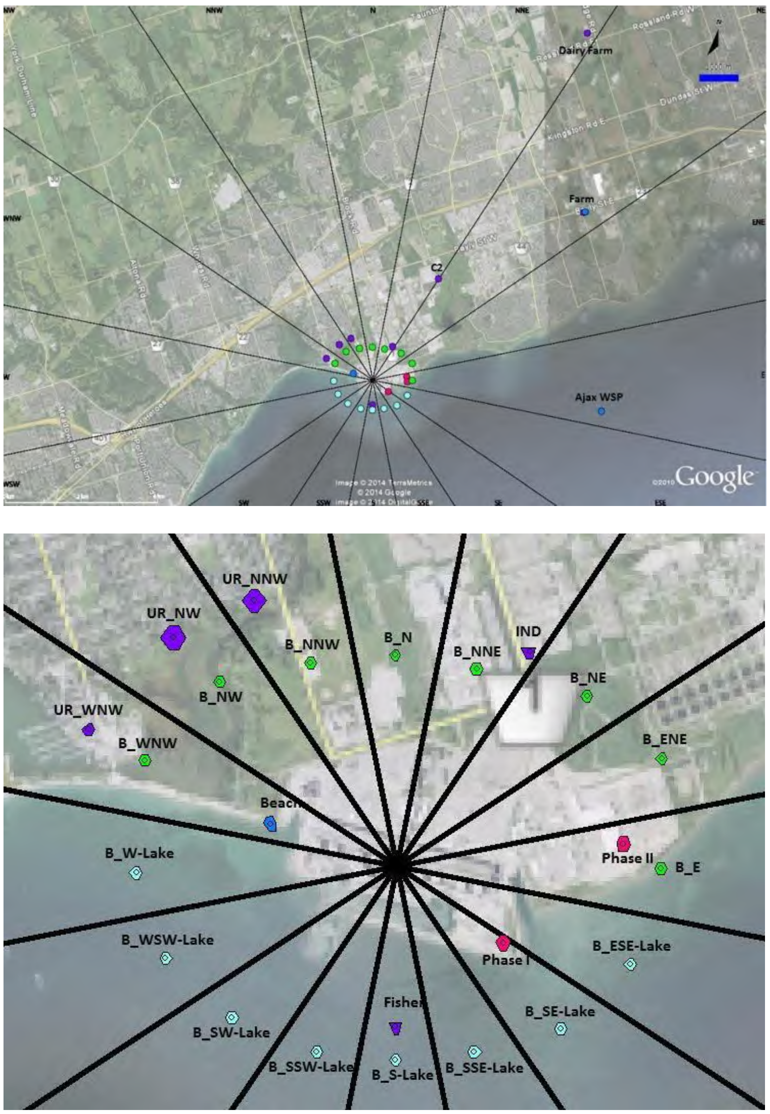
Age group	Location (see Figure 5-5)	Dose (µSv/a) per 1 Bq/s release rate			
		Kr-85	HTO	C-14	Co-60
Adult	B_E	1.50E-08	5.50E-07	2.20E-07	7.30E-02
	B_ENE	6.70E-09	2.50E-07	9.90E-08	4.20E-02
	B_NE	7.30E-09	2.70E-07	1.10E-07	5.10E-02
	B_NNE	1.90E-09	7.10E-08	2.80E-08	1.20E-02
	B_N	1.70E-09	6.50E-08	2.60E-08	1.20E-02
	B_NNW	1.90E-09	7.20E-08	2.90E-08	1.80E-02
	B_NW	2.10E-09	7.60E-08	3.00E-08	2.30E-02
	B_WNW	2.70E-09	1.00E-07	4.00E-08	3.20E-02
	B_W-Lake	3.90E-10	1.40E-08	5.70E-09	5.00E-06
	B_WSW-Lake	4.70E-10	1.70E-08	6.90E-09	6.00E-06
	B_SW-Lake	5.40E-10	2.00E-08	8.00E-09	6.90E-06
	B_SSW-Lake	8.10E-10	3.00E-08	1.20E-08	1.00E-05
	B_S-Lake	1.60E-09	6.10E-08	2.40E-08	2.10E-05
	B_SSE-Lake	6.80E-09	2.50E-07	1.00E-07	8.70E-05
	B_SE-Lake	7.80E-09	2.90E-07	1.10E-07	9.90E-05
	B_ESE-Lake	3.80E-09	1.40E-07	5.60E-08	4.90E-05
	Fisher	1.50E-10	5.70E-09	2.30E-09	2.00E-06
	C2	1.30E-09	4.80E-08	1.90E-08	9.40E-03
	IND	6.20E-10	2.30E-08	9.20E-09	7.90E-06
	UR_NNW	1.40E-09	5.90E-08	6.30E-07	1.30E-02
	UR_NW	1.60E-09	6.70E-08	9.10E-07	1.70E-02
	UR_NNW	2.10E-09	8.70E-08	1.10E-06	2.50E-02
	Dairy Farm NNE	2.10E-10	2.60E-08	2.80E-06	1.60E-03
	Farm NE	3.50E-10	4.00E-08	1.40E-06	2.30E-03
Child	B_E	1.50E-08	6.50E-07	3.10E-07	7.30E-02
	B_ENE	6.70E-09	3.00E-07	1.40E-07	4.20E-02
	B_NE	7.30E-09	3.20E-07	1.50E-07	5.10E-02
	B_NNE	1.90E-09	8.40E-08	4.10E-08	1.20E-02
	B_N	1.70E-09	7.70E-08	3.70E-08	1.20E-02
	B_NNW	1.90E-09	8.50E-08	4.10E-08	1.80E-02
	B_NW	2.10E-09	9.00E-08	4.30E-08	2.30E-02
	B_WNW	2.70E-09	1.20E-07	5.70E-08	3.20E-02
	B_W-Lake	3.90E-10	1.70E-08	8.20E-09	7.00E-06
	B_WSW-Lake	4.70E-10	2.10E-08	9.90E-09	8.40E-06
	B_SW-Lake	5.40E-10	2.40E-08	1.10E-08	9.80E-06
	B_SSW-Lake	8.10E-10	3.60E-08	1.70E-08	1.50E-05
	B_S-Lake	1.60E-09	7.20E-08	3.50E-08	3.00E-05
	B_SSE-Lake	6.80E-09	3.00E-07	1.40E-07	1.20E-04
	B_SE-Lake	7.80E-09	3.40E-07	1.60E-07	1.40E-04
	B_ESE-Lake	3.80E-09	1.70E-07	8.10E-08	6.90E-05
	Fisher	1.50E-10	6.80E-09	3.30E-09	2.80E-06
	C2	1.30E-09	5.80E-08	2.80E-08	9.40E-03
	UR_NNW	1.40E-09	7.70E-08	7.40E-07	1.30E-02
	UR_NW	1.60E-09	7.60E-08	8.00E-07	1.70E-02
	UR_NNW	2.10E-09	9.90E-08	9.90E-07	2.50E-02
	Dairy Farm NNE	1.90E-10	2.00E-08	2.80E-06	1.30E-03
	Farm NE	3.20E-10	2.30E-08	8.10E-07	1.90E-03

Age group	Location (see Figure 5-5)	Dose (μSv/a) per 1 Bq/s release rate			
		Kr-85	HTO	C-14	Co-60
Infant	B_E	1.90E-08	4.50E-07	2.10E-07	9.50E-02
	B_ENE	8.80E-09	2.00E-07	9.70E-08	5.50E-02
	B_NE	9.50E-09	2.20E-07	1.00E-07	6.70E-02
	B_NNE	2.50E-09	5.80E-08	2.80E-08	1.60E-02
	B_N	2.30E-09	5.30E-08	2.50E-08	1.60E-02
	B_NNW	2.50E-09	5.90E-08	2.80E-08	2.30E-02
	B_NW	2.70E-09	6.20E-08	3.00E-08	2.90E-02
	B_WNW	3.50E-09	8.20E-08	3.90E-08	4.10E-02
	B_W-Lake	5.10E-10	1.20E-08	5.60E-09	5.20E-06
	B_WSW-Lake	6.10E-10	1.40E-08	6.70E-09	6.30E-06
	B_SW-Lake	7.10E-10	1.60E-08	7.80E-09	7.30E-06
	B_SSW-Lake	1.10E-09	2.50E-08	1.20E-08	1.10E-05
	B_S-Lake	2.10E-09	5.00E-08	2.40E-08	2.20E-05
	B_SSE-Lake	8.80E-09	2.10E-07	9.80E-08	9.10E-05
	B_SE-Lake	1.00E-08	2.40E-07	1.10E-07	1.00E-04
	B_ESE-Lake	5.00E-09	1.20E-07	5.50E-08	5.10E-05
	Fisher	2.00E-10	4.70E-09	2.20E-09	2.10E-06
	UR_NNW	1.80E-09	4.70E-08	5.80E-07	1.70E-02
	UR_NW	2.10E-09	5.30E-08	6.40E-07	2.30E-02
	UR_NNW	2.70E-09	6.90E-08	7.80E-07	3.20E-02
	Dairy Farm NNE	2.50E-10	2.50E-08	5.00E-06	1.70E-03
	Farm NE	4.20E-10	1.60E-08	6.80E-07	2.40E-03

Table 5-5: Normalized Annual Doses from Chronic Releases at Phase II Site [3]

Age group	Location (see Figure 5-5)	Dose (µSv/a) per 1 Bq/s release rate			
		Kr-85	HTO	C-14	Co-60
Adult	B_E	2.63E-07	9.72E-06	3.89E-06	3.08E-01
	B_ENE	4.05E-08	1.50E-06	5.99E-07	2.87E-01
	B_NE	6.00E-09	2.22E-07	8.88E-08	4.05E-02
	B_NNE	4.16E-09	1.54E-07	6.16E-08	4.15E-02
	B_N	3.34E-09	1.23E-07	4.94E-08	3.72E-02
	B_NNW	3.06E-09	1.13E-07	4.52E-08	3.56E-02
	B_NW	2.51E-09	9.28E-08	3.72E-08	3.03E-02
	B_WNW	2.22E-09	8.20E-08	3.29E-08	2.54E-02
	B_W-Lake	2.54E-10	9.38E-09	3.76E-09	3.24E-06
	B_WSW-Lake	2.40E-10	8.86E-09	3.55E-09	3.07E-06
	B_SW-Lake	2.57E-10	9.50E-09	3.81E-09	3.29E-06
	B_SSW-Lake	3.47E-10	1.28E-08	5.14E-09	4.44E-06
	B_S-Lake	4.76E-10	1.76E-08	7.04E-09	6.08E-06
	B_SSE-Lake	9.35E-10	3.45E-08	1.38E-08	1.19E-05
	B_SE-Lake	2.33E-09	8.63E-08	3.45E-08	2.98E-05
	B_ESE-Lake	8.17E-09	3.02E-07	1.21E-07	1.04E-04
	Fisher	4.52E-11	1.67E-09	6.68E-10	5.77E-07
	C2	1.58E-09	5.83E-08	2.33E-08	1.11E-02
	IND	7.69E-10	2.84E-08	1.14E-08	9.84E-06
	UR_NNW	2.10E-09	8.74E-08	1.16E-06	2.41E-02
	UR_NW	1.96E-09	8.19E-08	1.10E-06	2.35E-02
	UR_NNW	1.80E-09	7.53E-08	1.03E-06	2.08E-02
	Dairy Farm NNE	2.30E-10	2.83E-08	3.06E-06	1.80E-03
	Farm NE	3.99E-10	4.59E-08	1.63E-06	2.65E-03
Child	B_E	2.63E-07	1.16E-05	5.55E-06	3.10E-01
	B_ENE	4.05E-08	1.78E-06	8.55E-07	2.87E-01
	B_NE	6.00E-09	2.64E-07	1.27E-07	4.05E-02
	B_NNE	4.16E-09	1.83E-07	8.79E-08	4.15E-02
	B_N	3.34E-09	1.47E-07	7.04E-08	3.72E-02
	B_NNW	3.06E-09	1.34E-07	6.45E-08	3.56E-02
	B_NW	2.51E-09	1.10E-07	5.30E-08	3.04E-02
	B_WNW	2.22E-09	9.75E-08	4.69E-08	2.54E-02
	B_W-Lake	2.54E-10	1.12E-08	5.36E-09	4.58E-06
	B_WSW-Lake	2.40E-10	1.05E-08	5.06E-09	4.33E-06
	B_SW-Lake	2.57E-10	1.13E-08	5.43E-09	4.64E-06
	B_SSW-Lake	3.47E-10	1.53E-08	7.33E-09	6.27E-06
	B_S-Lake	4.76E-10	2.09E-08	1.00E-08	8.58E-06
	B_SSE-Lake	9.35E-10	4.11E-08	1.97E-08	1.69E-05
	B_SE-Lake	2.33E-09	1.03E-07	4.93E-08	4.21E-05
	B_ESE-Lake	8.17E-09	3.59E-07	1.73E-07	1.47E-04
	Fisher	4.52E-11	1.98E-09	9.53E-10	8.15E-07
	C2	1.58E-09	6.93E-08	3.33E-08	1.11E-02
	UR_NNW	2.10E-09	9.99E-08	1.02E-06	2.41E-02
	UR_NW	1.96E-09	9.35E-08	9.72E-07	2.35E-02
	UR_NNW	1.80E-09	8.59E-08	9.12E-07	2.08E-02
	Dairy Farm NNE	2.12E-10	2.23E-08	3.09E-06	1.48E-03
	Farm NE	3.68E-10	2.60E-08	9.30E-07	2.17E-03

Age group	Location (see Figure 5-5)	Dose (μSv/a) per 1 Bq/s release rate			
		Kr-85	HTO	C-14	Co-60
Infant	B_E	3.43E-07	7.97E-06	3.79E-06	4.00E-01
	B_ENE	5.28E-08	1.23E-06	5.84E-07	3.73E-01
	B_NE	7.82E-09	1.82E-07	8.65E-08	5.27E-02
	B_NNE	5.43E-09	1.26E-07	6.00E-08	5.39E-02
	B_N	4.35E-09	1.01E-07	4.81E-08	4.83E-02
	B_NNW	3.99E-09	9.27E-08	4.41E-08	4.63E-02
	B_NW	3.28E-09	7.61E-08	3.62E-08	3.94E-02
	B_WNW	2.90E-09	6.73E-08	3.20E-08	3.30E-02
	B_W-Lake	3.31E-10	7.69E-09	3.66E-09	3.42E-06
	B_WSW-Lake	3.13E-10	7.27E-09	3.46E-09	3.23E-06
	B_SW-Lake	3.35E-10	7.80E-09	3.71E-09	3.47E-06
	B_SSW-Lake	4.53E-10	1.05E-08	5.01E-09	4.69E-06
	B_S-Lake	6.20E-10	1.44E-08	6.85E-09	6.41E-06
	B_SSE-Lake	1.22E-09	2.83E-08	1.35E-08	1.26E-05
	B_SE-Lake	3.04E-09	7.08E-08	3.36E-08	3.15E-05
	B_ESE-Lake	1.07E-08	2.48E-07	1.18E-07	1.10E-04
	Fisher	5.89E-11	1.37E-09	6.51E-10	6.09E-07
	UR_NNW	2.74E-09	7.00E-08	8.09E-07	3.14E-02
	UR_NW	2.56E-09	6.56E-08	7.70E-07	3.05E-02
	UR_NNW	2.35E-09	6.03E-08	7.23E-07	2.70E-02
	Dairy Farm NNE	2.77E-10	2.77E-08	5.48E-06	1.92E-03
	Farm NE	4.81E-10	1.79E-08	7.86E-07	2.82E-03



	Distance from release location to receptor	
Receptor	Phase 1 (km)	Phase 2 (km)
B_N	1.2	1.1
B_NNE	1.1	0.8
IND	1.2	0.8
B_NE	1.0	0.5
B_ENE	1.0	0.4
B_E	0.7	0.3
B_ESE-Lake	0.4	0.5
B_SE-Lake	0.4	0.7
B_SSE-Lake	0.4	1.0
B_S-Lake	0.5	1.1
Fisher	0.5	1.1
B_SSW-Lake	0.8	1.4
B_SW-Lake	1.1	1.7
B_WSW-Lake	1.2	1.7
B_W-Lake	1.4	1.9
B_WNW	1.6	1.9
Beach	1.0	1.3
UR_WNW	1.8	2.2
B_NW	1.4	1.6
UR_NW	1.7	1.9
B_NNW	1.4	1.3
UR_NNW	1.6	1.7
C2	3.2	2.6
Dairy Farm	10.5	9.9
Farm	6.9	6.3
Ajax WSP	6.2	5.8

Figure 5-5: Near- and Far-Site Critical Group Receptor Locations for PWMF Safety Assessment

Notes: Locations included in the model are those identified by the Pickering site survey [12] and hypothetical locations along Pickering site exclusion zone boundary. For landside hypothetical locations, receptors were assumed to be at their locations 100% of the time. Receptors at the lakeside hypothetical locations were assumed to be present at that location 1000h per year.

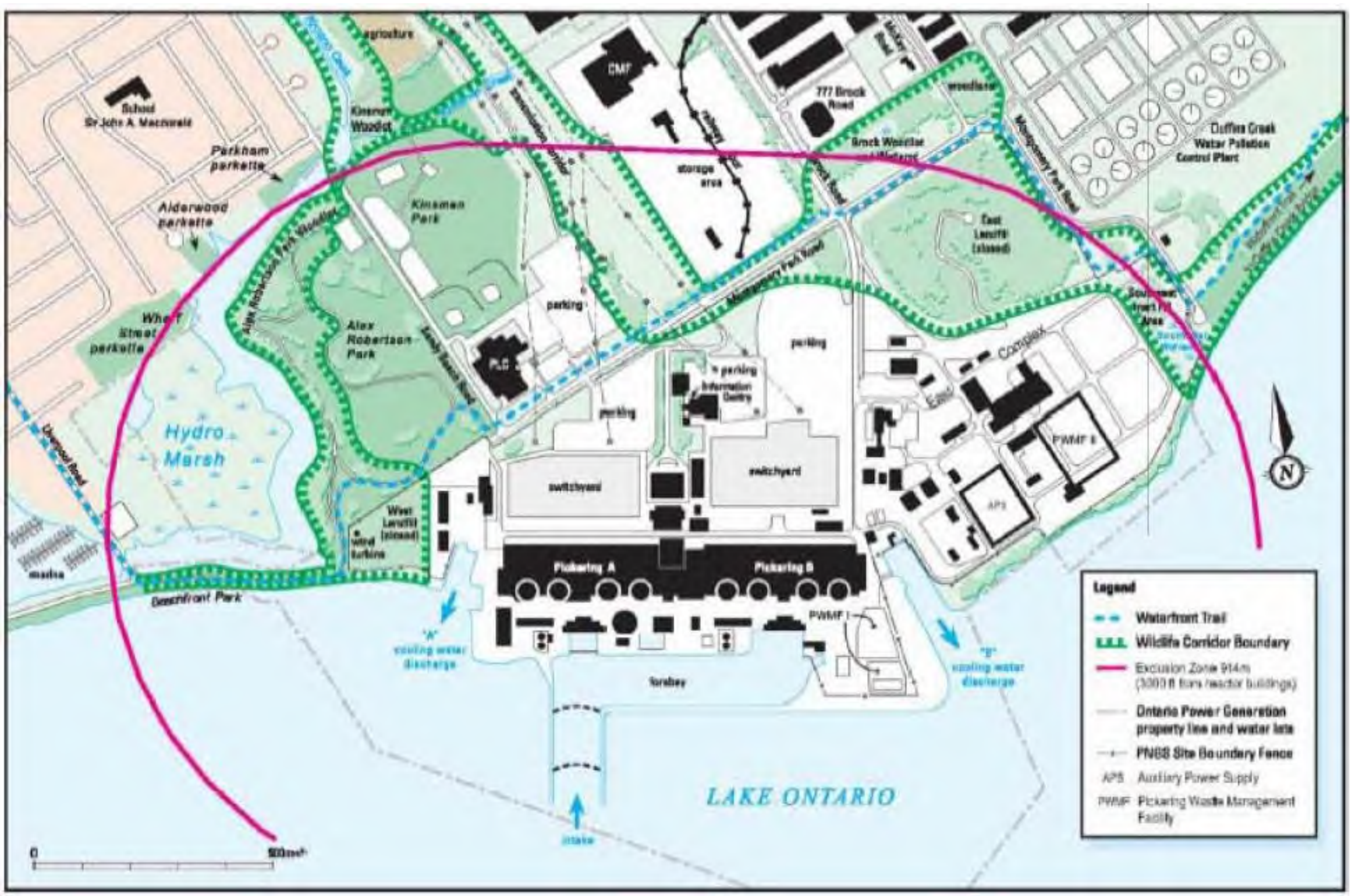


Figure 5-6: Pickering Site

Table 5-6: Annual Individual Dose from PWMF Normal Operation Considering DSCs Containing 6 Year Decayed Used Fuel[15]

Radiation Source	Maximum Annual Individual Dose (μSv/a)	Dose Receptor Location	Notes
External gamma radiation from DSCs and DSMs. Including storage of DSCs containing 6 year decayed used fuel in SB3.	3.56E+00	PNGS site boundary[a]	Based on the Best Estimate + 2σ dose rate at Montgomery Park Rd turnaround (1.78×10^{-3} μSv/h [9]) and 2000 hours annual occupancy. The listed dose and dose rate are due to the DSCs in the Phase II site. The contribution from DSCs and DSMs in the Phase I site is negligible [11].
	1.64E+00	Lakeside exclusion zone boundary	Based on the Best Estimate + 2σ dose rate at the lake where the shoreline intersects with the land site boundary (1.64×10^{-3} μSv/h [9]) and 1000 hours[b] annual occupancy for boaters and fishermen.
Chronic particulate emission from PWMF measurements reported in quarterly reports.	6.02E-04	PNGS site boundary	Based on 2.00×10^{5} Bq/a release from Phase I site (Table 5-1).
	1.01E-07	Lakeside exclusion zone boundary	
Postulated volatile releases from DSC processing.	1.18E-03	PNGS site boundary	Based on 280 failed elements per year from Phase I site.
	7.02E-05	Lakeside exclusion zone boundary	
Postulated release from DSMs.	1.57E-04	PNGS site boundary	Based on $1.60 \text{X} 10^{10}$ Bq/a carbon-14 release from Phase I.
	9.26E-06	Lakeside exclusion zone boundary	
Total annual individual dose	**3.56E+00**	**PNGS site boundary**	**The limiting annual individual dose for a member of the public is 0.4% of the 1 mSv regulatory limit.**
	1.64E+00	**Lakeside exclusion zone boundary**	

Notes:
a) The PNGS boundary is selected because of it is the location with the potential highest dose. There is no temporary or permanent population at the PNGS boundary. A conservative occupancy of 2000 hours per year is assigned for receptors at the hypothetical landside boundary locations. The partial occupancy is conservative since the location is not identified as one of the potential critical group representative locations around the Pickering site [12]. External gamma dose rates at representative locations identified in Reference [12] will be significantly lower than the dose rate at Montgomery Park Rd and are expected to be indistinguishable from the natural background radiation level.
b) The 1000 hours per year occupancy assumption is significantly more conservative than the 1% (~88 hours per year) occupancy factor assumed in the PNGS assessment and site-specific survey [12].

15 Considering 70 DSCs containing 6 year decay used fuel (of 230 MWh/kgU burnup) are processed in a year of operation of the PWMF and the releases outlined in Section 5.3.1.

5.3.4 Worker Dose

The worker doses during normal operation of the PWMF were estimated based on the recorded doses from the PWMF quarterly reports (92896-REP-00531-* series of reports). The maximum recorded individual whole body dose for PWMF worker during the period of 2007-2019 is 1.6 mSv[16], which is 3% of the 50 mSv dose limit and 53% of the 3 mSv ALARA dose target. The highest annual dose is typically for an individual in the Operations group.

At most, if every DSC processed in a year contained 6 year decayed used fuel, collective dose could be expected to increase by a factor of 2.6 (see Footnote 17). However, since not all DSCs will contain 6 year decayed used fuel, and the individual dose will be managed by the existing OPG Radiation Protection Program [13], worker doses are expected to remain well within the 3 mSv ALARA dose target documented in the PWMF Safety Report [1].

5.4 Malfunctions and Accidents

5.4.1 Screening of Potential Accident Scenarios and Identification of Bounding Accident Scenarios

5.4.1.1 Hazard Identification

The basis of the PWMF hazard identification is the list of internal hazards [14] and external hazards [15] developed in support of OPG's Probabilistic Safety Assessment (PSA) guide. This list is supplemented, as applicable, by hazards derived from other PWMF documentation.

5.4.1.2 Pre-Screening of Existing Hazards

A pre-screening of the identified hazards was undertaken to screen out those events which are known to have no impact on the Pickering site or PWMF. Hazards may be eliminated at this stage when it can easily be determined without any additional analysis, that the hazard has a negligible impact on the safety of the PWMF. Hazards that are screened in are then part of the detailed screening analysis. Appendix B lists the results of the hazard pre-screening assessment.

5.4.1.3 Events Screening

Potential hazards associated with the on-site transfer, processing and storage in SB3 of the lower-fuel-age DSC, containing 6 year decayed used fuel, and transfer of a number of existing DSCs between SB3 and SB4, were identified and the events were screened in or out. Events that were screened out were deemed to be incredible (the frequency is less than 10^{-6} events per year) or to have a negligible contribution to risk. This process followed the OPG screening criteria (References [14] and [15], as applicable) against which the events were assessed and summarily dismissed.

First, a qualitative screening was conducted to identify hazards that were judged to have negligible impact on risk without the need to perform any detailed quantitative assessments. Part of the

[16] The maximum recorded individual whole body dose of 1.6 mSv occurred in 2008 for an individual of the Civil Maintenance group.

[17] As identified in Section 5.3.2.1, compared to a DSC containing 10 year decayed used fuel the dose rate at 1 m from a single DSC containing 6 year decayed used fuel may increase by a factor of 2.6.

qualitative screening was performed during hazard pre-screening documented in Appendix B. Some of the identified hazards may not have an impact on the DSC due to its location and orientation with respect to the rest of the structures, or certain hazards may not be applicable due to consideration of those hazards during design. Hazards that have been determined to not have any impact on radiological consequence were screened out.

A quantitative screening criteria based on event frequency has also been applied if the event was not already screened out based on qualitative criteria. CSA N292.0-14 [4], which provides guidance for the management of radioactive waste and irradiated fuel, defines a credible abnormal event as a naturally occurring or human generated event or event sequence that has a frequency of occurrence equal to or greater than 10^{-6} events per year. Using this definition of a credible event, an event screening frequency of 10^{-6} events per year was applied to quantitative screening.

Assumptions listed in Table 5-7 were applied for event screening.

Table 5-7: Assumptions for Events Screening

Assumption	Justification
The probability of a human error is assumed to be 10^{-3} per movement or activity.	NUREG/CR-1278 [16] provides an estimated human error probability of 0.001 for an operator placing a manual control in an incorrect setting.
100 DSCs containing 6 year decayed used fuel will be transported within one year from the Station IFB to the Phase I Processing Building and from the Processing Building to SB3.	The transfer of 100 lower-fuel-age DSCs in one year is a conservative, bounding value.
A total of 119 existing DSCs stored in SB3 will be moved to SB4 to accommodate the arrival of 100 DSCs with lower-fuel-age into SB3. 19 of the 119 existing DSCs will be moved back from SB4 to the SB3 and placed between the DSCs containing 6 year decayed used fuel and the aisle. These DSC moves will occur within one year.	Refer to Figure 5-2 for DSCs layout in SB3. The move of the existing 119 DSCs between SB3 and SB4 within one year is a conservative, bounding value.
The maximum speed of the DSC transporter is 12 km/h (GEN IV) [17]. The total distance the Transporter needs to travel between the Station IFB to the Phase I Processing Building and from the Processing Building to SB3 is approximately 2 km. However, the travel time of the Transporter is conservatively assumed to take a longer time and be on the road for 1 hour.	Conservatively slow speed maximizes time-at-risk for hazards while the DSC is in transit.

Assumption	Justification
Buildings and structures designed based on NBCC 1995 or prior are assumed to collapse at a frequency of $2x10^{-3}$/year. The PWMF Phase I Processing Building was designed based on NBCC 1990 [3]	Although it can be damaged, the NBCC requires the structure to not collapse at the specified seismic risk level. However, with no supporting analysis to determine when the structure actually fails, the frequency of building failure is assumed to be equivalent to the earthquake frequency. The seismic risk for NBCC 1995 is based on an earthquake with a 500 year return period. 1/500 years = $2x10^{-3}$ events/year
Buildings and structures designed based on NBCC 2005 or later are assumed to collapse at a frequency of $4x10^{-4}$/year [3].	The seismic risk for NBCC 2005 and later is based on an earthquake with a 2500 year return period. 1/2500 years = $4x10^{-4}$ events/year
The functional and performance requirements for DSCs containing 10 year decayed used fuel [18] apply to DSCs loaded with 6 year decayed used fuel.	Because the Design Requirements for a DSC loaded with 6 year decayed used fuel are not currently available, it is assumed that the DSC functional and performance requirements in a DSC containing 10 year decayed used fuel [18], will also be requirements in the Design Requirements for a DSC loaded with 6 year decayed used fuel. This assumption is part of the work scope and may be re-visited when the Design Requirements for a DSC containing 6 year decayed used fuel are issued.

5.4.2 Malfunctions/Accidents during DSC On-Site Transfer

It is conservatively assumed that 100 lower-fuel-age DSCs will be transferred from the Station IFBs to the Phase I Processing Building and after processing the seal-welded DSCs will be transferred to the SB3, within one year.

During normal operation of the existing UFDS facility, up to 70 DSCs are transferred from the PNGS IFB for processing each year that will be stored in either the Phase I or Phase II storage buildings. Hazard frequencies documented in Reference [3] have been calculated based on this number.

In summary, the present hazard screening assessment focuses on the 100 lower-fuel-age containers to be transferred from the Stations' Irradiated Fuel Bay (IFB) for processing and then to storage in SB3 within one year, and hazard frequencies were calculated accordingly.

5.4.2.1 Transporter Failure

5.4.2.1.1 Between the Station IFB and Processing Building

The transporter, carrying a loaded DSC, travels on the south side of the powerhouse between the PBIFB and the DSC Processing Building. From the Pickering A AIFB the transporter travels on the north side of the powerhouse to the DSC Processing Building [19].

In the event of Transporter failure, the containment barrier provided by the transfer clamp and elastomeric seal is assumed to fail [1] as a result of the longer than expected time taken to transfer the DSC from the Pickering B Primary Irradiated Fuel Bay (PBIFB) or from the Pickering A Auxiliary Irradiated Fuel Bay (AIFB) to the DSC Processing Building.

Conservatively it is assumed that the free inventory of tritium, carbon-14, and krypton-85 in four damaged fuel elements is released into the DSC cavity (if 1 percent of all bundles contain one damaged element, there would be approximately four damaged elements in each DSC). The barrier provided by the transfer clamp and elastomeric seal are ignored and these radionuclides are considered to be released at once into the environment.

Based on the PWMF and Western Waste Management Facility (WWMF) operating experience, the frequency for this event is 3 events per year [1]. This event is screened in.

5.4.2.1.2 Between the Processing Building and SB3

The scenario is a Transporter failure while transferring a seal-welded DSC from the PWMF Phase I Processing Building to the Phase II SB3. Both the fuel sheath and the DSC lid seal-weld must fail for a release of radionuclides to occur. Used fuel having a known damaged or defective sheath is not loaded into a DSC. Failure of the sheath is not expected to occur during the on-site transfer of the DSC. The lid closure weld is a groove weld between the base plate of the lid and the perimeter flange of the base. After the weld has been completed and cooled, a Phased Array Ultrasonic Testing (PAUT) system is used for the inspection of the DSC lid-to-base seal-weld. The DSC is subsequently filled with inert helium and leak tested prior to storage.

As there is no external force acting upon the DSC, it is considered that a longer than expected transfer time from the Processing Building to the SB3 associated with transporter failure will not have any impact on the integrity of the seal-welded DSC. This event is screened out.

5.4.2.2 Transporter Operator Health-Related Emergency

The Transporter operator could have a health-related emergency resulting in loss of consciousness during the DSC transfer. The Transporter operates at low speed and is escorted by at least one person in addition to the driver. The second person could intervene to stop the Transporter. Even if operator illness were to result in the Transporter leaving the road, a release of radioactivity from a DSC is not expected given the design of the DSC and the transfer clamp with elastomeric seal or the seal-weld. The dose consequences from this postulated scenario would be within the envelope of those of the container drop presented in Section 5.4.2.3. This event is screened out.

5.4.2.3 Dry Storage Container Drop during On-Site Transfer

Transporter design features and administrative control requirements are expected to ensure that the Transporter will not collide with another vehicle during DSC transfer.

However, a possible scenario involving collision of the DSC Transporter with another vehicle, resulting in the drop of the DSC, could take place during the on-site transfer of the DSC:

- Between the station IFB and the Phase I Processing Building; along this transfer route the transporter carries a DSC with transfer clamp. The transfer clamp has been designed to withstand the impact resulting from collision with another vehicle, and will ensure that the lid will stay on the DSC [3]. Therefore, only the airborne release of tritium, carbon-14, and krypton-85 from the DSC cavity is considered for this assessment.
- Between the PWMF Phase I Processing Building and Phase II SB3: along this transfer route a transporter carries a seal-welded DSC. Although the seal-weld is extremely robust, the collision is postulated to compromise the seal-weld.

Even though high level of control and security is maintained for the transfer route, a considerable impact may occur with another vehicle during the DSC transfer. Therefore, failure of 100 percent of a clamped or seal-welded DSC's used fuel content is assumed, i.e., 100 percent of the fuel elements in all the 384 fuel bundles, for a total of 10,752 (384x28) failed fuel elements [3]. The free inventory of tritium, carbon-14 and krypton-85 in the damaged fuel elements is assumed to be released into the DSC cavity. Ignoring the barrier provided by the transfer clamp or seal-weld, it is assumed that the radionuclides are released at once into the environment.

This event is screened in.

5.4.2.4 Fire

The potential for an accident involving DSC contact with a source of combustible material during on-site transfer has been considered. Fire sources directly along the transfer route of the DSC include acetylene cylinders and propane gas tanks [20], and the fuel tanks of other vehicles.

The combustible materials that could be contributed by the Transporter itself are the diesel fuel in the tank, engine lubricating oil and hydraulic oil. It is expected that such a fire would be of short duration. The duration of the fire would be further limited as a result of the fire detection and suppression systems in the Transporter design and the expected response of the PNGS emergency response team as the primary responder inside the PNGS protected area.

The effect of a fire could potentially be to increase the temperature of the DSC and the used fuel bundles inside the DSC. A thermal analysis was conducted to investigate the heating and cooling process of a DSC during and after a fire of the DSC transporter carrying a container: the DSC in transfer is on the Transporter, located in the fire, refer to Section D4.5.3 of [21]. It was concluded, that given the large thermal inertia of the DSC and the limited duration of the event, the fire scenario involving a DSC would not breach the containment and will not result in radiological release.

This event is screened out.

5.4.2.5 Adverse Road Conditions

Procedural controls are in place to prohibit DSC transfer under poor road conditions or until potentially slippery conditions can be corrected by sanding or salting of the transfer route. Even if the transporter were to lose traction on a slippery surface resulting in the vehicle leaving the road, a release of radioactivity from a clamped or seal-welded DSC is not expected given the robust design of a DSC. In the worst case scenario, where the transporter topples over as a result of adverse road conditions, the radiological consequences would be within the envelope of those described in Section 5.4.2.3.

Therefore, this event can be screened out.

5.4.2.6 Earthquake

The Pickering B Design Basis Earthquake (DBE) is defined as an earthquake with peak ground acceleration (PGA) of 0.05g and a frequency of reoccurrence of once in 1000 years [22]. The integrity of the DSC has been evaluated by determining its stability against overturning and sliding under the postulated DBE seismic acceleration [23]. The seismic ground response spectrum of the PNGS B site was used for the evaluation.

Since the Transporter with a DSC is not on the road 100 percent of the time, the combined occurrence of having a DBE and the Transporter on the road simultaneously was calculated. As mentioned in Section 5.4.2, frequencies for DSC transfer were calculated based on the 100 lower-fuel-age containers to be transferred between the stations' IFB to the SB3 via the Processing Building.

The following assumptions were made:

- 100 lower-fuel-age DSCs are transferred within one year from the station IFBs to the Processing Building and from the Processing Building to SB3;
- The transporter is assumed to travel up to a maximum speed of 12 km/h, refer to Table 5-7;
- The total distance the Transporter needs to travel is approximately 2 km: between the AIFB and the DSC Processing Building is approximately 1 km [24] and from the Processing Building to SB3 is approximately 1 km [25], [1]; and
- The Transporter is conservatively assumed to take a longer transfer time and be on the road for 1 hour to increase the time at risk.

With these assumptions, the probability of finding a loaded DSC in transit during a 1-year period would be:

$$100 \times 1 \times (1/24) \times (1/365) = 1.14 \times 10^{-2}$$

The frequency of a DBE occurring at a time when a lower-fuel-age DSC is being transferred is:

$$(1 \times 10^{-3}) \times (1.14 \times 10^{-2}) = 1.14 \times 10^{-5} \text{ events/year}$$

This event cannot be screened out based on frequency. However, in the worst case scenario, where the Transporter topples over and drops the DSC as a result of a seismic event, the radiological consequences, as per the Safety report [1], would be within the envelope of those in Section 5.4.2.3. This event is screened out.

5.4.2.7 Tornadoes

Tornadoes normally occur in unstable atmospheric conditions when warm moist air comes into contact with cold air. A tornado is a rotating thunderstorm with a vortex of air extending downward from a thundercloud. The strong updraft in a thunderstorm interacts with strongly sheared winds causing rotation of the updraft that intensifies to become a tornado.

The Design Basis Tornado (DBT) defined for the Darlington nuclear site [26] is defined as follows:

- Rotational wind speed of 322 km/h,
- Translational wind speed of 96 km/h,
- Pressure drop of 9.6 kPa,
- Rate of pressure drop of 5.6 kPa/s and
- Radius of maximum rotational wind speed of 46 m.

These parameters are considered to be large enough to envelope any credible tornadoes in southern Ontario [26]. Based on the PNGS site wind speed frequencies listed in Table 1 of Reference [27], the DBT-definition rotational wind speeds correspond to a mean frequency of 3.13×10^{-6} events/year.

During tornado winds, objects can be picked up by the wind forces and accelerated to high velocities. Reference [26] has an established spectrum of tornado- generated missiles considered in the Darlington Nuclear Generating Station (DNGS) design as part of the DBT. The following tornado-generated missiles have been assessed for their impact on the clamped DSC during on-site transfer:

a) Woodplank, 102 mm × 305 mm × 3.7 m, weight 91 kg, velocity 335 km/h (80 percent of total tornado velocity, rotational plus translational).

b) Steel pipe, 76 mm diameter, schedule 40, 3 m long, weight 35.4 kg, velocity 168 km/h (40 percent of total tornado velocity).

c) Steel rod, 25 mm diameter × 914 mm long, weight 3.6 kg, velocity 251 km/h (60 percent of total tornado velocity).

d) Steel pipe, 152 mm diameter, schedule 40, 4.6 m long, weight 129 kg, velocity 168 km/h (40 percent of total tornado velocity).

e) Steel pipe, 305 mm diameter, schedule 40, 4.6 m long, weight 337 kg, velocity 168 km/h (40 percent of total tornado velocity).

f) Utility pole, 343 mm diameter, 10.7 m long, weight 676 kg, velocity 168 km/h (40 percent of total tornado velocity).

g) Automobile, frontal area 1.9 m^2, weight 1,800 kg, velocity 84 km/h (20 percent total tornado velocity).

Safety of the DSC against overturning was investigated for a severe wind load simulating a tornado wind speed of 425 km/h [23]. The analysis showed that the transfer clamp will keep the lid in place, the containment will not be breached, and the DSC will not overturn under the impact of postulated missiles during on-site transfer.

As calculated in Section 5.4.2.6, the frequency of having a loaded DSC transferred from the station's IFB to the SB3 via the Phase I Processing Building is 1.14×10^{-2} events/year. The frequency of a tornado occurring at the time when a DSC is being transferred is

$$1.14 \times 10^{-2} \times 3.13 \times 10^{-6} = 3.57 \times 10^{-8} \text{ events/year},$$

which is below the cut-off frequency of 10^{-6} per year. Therefore, this event can be screened out.

5.4.2.8 Thunderstorms

Thunderstorms can potentially involve lightning striking a loaded DSC on the Transporter during on-site transfer.

According to the DSC design requirements [18], the DSC was designed to maintain its structural integrity, appropriate shielding and containment function for severe atmospheric conditions during on-site transfer. As severe atmospheric conditions are within the design basis of the DSC, this hazard is screened out.

5.4.2.9 Flooding

The only possibility for flooding at the Pickering site would be as a result of extreme local meteorological events. A review level Probable Maximum Precipitation (PMP) has been developed to be used at the OPG sites [28], which represents a rainfall of 420 mm in a 12-hour period, of which 51% (214 mm) fall within a one hour period.

Transfer procedures require that loaded DSC not to be transferred during anticipated extremely adverse weather conditions. In addition, sufficient warning time should be available for site staff to prevent this scenario from occurring.

If transfer of a lower-fuel-age DSC during an extreme rainfall were to occur, extensive flooding would likely affect the operation of the Transporter, however it is not expected to have any detrimental effect on the DSC. The DSCs are designed to tolerate water immersion at 2MPa [18], so the temporary flooding waters would not be of a concern to radiological safety. This event is screened out.

5.4.2.10 Explosions along the Transfer Route during Dry Storage Container Transfer

There are several sources of explosion along the on-site transfer route of the DSCs from the AIFB/IFB to the Phase I Processing Building [24], such as acetylene cylinders and compressed gas bottle storage facility. Explosions originating from handling accidents of acetylene cylinders, compressed gas bottle explosion and pressure vessel burst leading to missiles due to normal wear and tear of oxygen, nitrogen or air cylinders have been assessed in Section 5.6 of Reference [24], and the combined hazard frequency has been calculated to be 9.74×10^{-8} events/year, lower than the 10^{-6} cut-off frequency. Thus, this hazard is screened out based on frequency.

Explosion hazards along the onsite transfer route of the DSC from the PWMF Phase I Processing Building to the Phase II SB3 have been assessed [20]. The following fire and non-fire initiated hazard scenarios have been taken into consideration to be capable of toppling a passing DSC:

- Acetylene cylinder detonation
- Propane storage tank BLEVE (Boiling Liquid Expanding Vapour Explosion)
- Vapour cloud explosion (VCE) due to a propane storage tank rupture.

The combined explosion frequency of the above-mentioned hazards on the DSC in transfer has been determined to be 5.2×10^{-8} per year, refer to Section 3.4 of Reference [20]. The calculations were done assuming 20 DSC shipments a week (about 1000 shipments per year), which is considerably a higher number than the assumed annual shipments of 100 lower-fuel-age DSCs to SB3. The explosion hazard frequencies calculated above are lower than the 10^{-6} cut-off frequency, therefore this hazard is screened out.

5.4.2.11 Turbine Missile Strike

The frequency of turbine missiles impacting structures, systems and components (SSCs) has been determined in Section 6.2.1 of Reference [28] to be 6×10^{-6} events/year.

The probability of having a loaded DSC in transit between the Phase I Processing Building and SB3 is 1.14×10^{-2} over a year, refer to Section 5.4.2.6.

The frequency of turbine missiles impacting a loaded DSC while the DSC is being transferred from the IFB to the Processing Building or from the Processing Building to Storage Building 3 is:

$6 \times 10^{-6} \times 1.14 \times 10^{-2} = 6.84 \times 10^{-8}$ events/year,

which is below the event cut-off frequency of 10^{-6}/year. This hazard is screened out.

5.4.2.12 Aircraft Crash

The probability of an aircraft strike is proportional to the target area.

To assess this hazard, the size of the Liftking transporter was used as it is slightly larger than the GEN IV transporter. The transporter has an overall length of 27.833 ft (8.5 m), an overall width of 10.875 ft (3.3 m) and an overall height of 15.521 ft (4.7 m) [17].

Using total crash rates determined for the PNGS site [28], the aircraft impact frequency on the transporter has been calculated, considering the limited time that a loaded transporter will be in transit and taking into account that the transporter is a small moving target.

The frequency of an aircraft crash impacting the transporter carrying the DSC during on-site transfer is 4.12×10^{-10} events/year (see Appendix C), which is below the 10^{-6} cut-off frequency and therefore this hazard can be screened out.

5.4.2.13 Toxic Gas Release - Chlorine originated from Ajax Water Treatment Plant

The Ajax Water Treatment Plant uses chlorine cylinders for water treatment. The facility is located at approximately 4.1 km from the Phase II site. The facility is in the route of the DSC onsite transfer from the Processing Building to SB3. The Screening Distance Value (SDV) for chlorine is 4.4 km [15], hence this hazard cannot be screened out based on distance.

Chlorine leak from the Ajax Water Treatment Plant can have an impact on the Transporter operator ability to keep the Transporter safely on road. However, even if the operator illness were to result in the Transporter leaving the road, the impact of this hazard would be bounded by the DSC drop as a result of the Transporter collision with another vehicle, refer to Section 5.4.2.3. This event is screened out.

5.4.2.14 Soil Failures/Slope Instability

It has been identified that the DSC transport route between the AIFB/ IFB and the DSC Processing Building has some anomalous portions and a detailed geotechnical assessment has been recommended [24].

In the worst case scenario, where the Transporter topples over and drops the clamped or seal-welded DSC as a result of soil failure, the radiological consequences would be within the envelope of those in Section 5.4.2.3.

This event is screened out.

5.4.3 Malfunctions/Accidents during Processing

5.4.3.1 Drop of a Dry Storage Container during Handling

Failure of the crane, the lifting beam, lift plates, or the DSC trunnions could potentially result in dropping a loaded DSC while it is being lifted during operations at the DSC Processing Building.

The failure probability of a crane lifting very heavy loads, based on US nuclear plant operating experience, (Section 3.5 of NUREG-1774 [29]), is estimated to be 5.6×10^{-5} per demand. Based on the combined operating experience of the PWMF and WWMF, the number of lifts to be carried out in the DSC Processing Building using the crane is approximately 600 per year [1]. Therefore, the total postulated frequency of crane failure would be

$5.6 \times 10^{-5} \times 600 = 3.36 \times 10^{-2}$ events per year, which is greater than the cut-off frequency of 10^{-6}.

A handling accident involving the dropping or tip over of multiple DSCs is not considered to be a credible event. The normal lift height of a DSC in the Processing Building with transfer clamp installed is 200 mm. Should a crane accident result in the drop of a clamped DSC or seal welded DSC, the low lift height inside the DSC Processing Building would reduce the likelihood of the container from tipping over and striking a second DSC.

Realistically, fuel sheath failure is not expected to result from an accidental DSC drop from the low lift height of the crane in the DSC Processing Building. In the worst-case scenario, dropping a clamped DSC during handling is not expected to result in failure of more than 30 percent of a DSC's used fuel elements, a total of 3,226 failed fuel elements (0.3x384x28) [1]. The free inventory of tritium, carbon-14 and krypton-85 in the damaged fuel elements is assumed to be released into the

DSC cavity. The barrier provided by the transfer clamp seal is ignored and these radionuclides are assumed to be released at once into the environment. This event is screened in.

5.4.3.2 Equipment Drop onto a Dry Storage Container

The crane auxiliary hoist is used to handle other processing equipment, including the DSC transfer clamp, lid welding equipment, and vacuum bell jar lid. A structural failure of any lifting/rigging equipment such as slings, shackles, or other specialty equipment lifting points or lifting beams while suspended by the auxiliary crane could result in a drop of equipment onto the lid of a loaded DSC.

These accident scenarios are unlikely given that the rated load capacity of the auxiliary hoist and the lifting/rigging equipment are not exceeded and routine inspections and pre-operational checks will be performed.

However, to calculate the event frequency of equipment dropping onto a DSC, the following assumptions were made:

- A maximum of 100 lower-fuel-age DSCs will be processed within an year;
- A total of four pieces of equipment have the potential to drop onto a DSC lid [1];
- With the exception of the transfer clamp, each structure is lifted twice over the DSC (installation and removal), totaling seven lifts per DSC [1].

Assuming that the probability of the equipment failure is 5.6×10^{-5}, the total frequency of a drop of equipment onto a loaded DSC lid would be:

$$5.6 \times 10^{-5} \times 100 \times 7 = 3.92 \times 10^{-2} \text{ events per year.}$$

Given that the lift height of equipment over a loaded DSC is limited by procedural controls, the dose consequences from this scenario would be bounded by the drop of a dry storage container described in Section 5.4.3.1. Therefore, this event is screened out.

5.4.3.3 Dry Storage Container Collision during Craning

A DSC craning accident due to operator error could result in a loaded DSC colliding with another DSC (loaded or empty) on the DSC Processing Building floor or with other process building equipment or structure.

Assuming that 100 lower-fuel-age DSCs are processed within a one year period, the total number of times a loaded and unwelded DSC is lifted would be approximately 110 (one lift per DSC plus 10 percent of them are assumed to have weld failure and require weld repairs). The assumed operator error probability is 10^{-3} per movement [16].

The postulated frequency of a loaded and unwelded DSC craning collision accident is

$$10^{-3} \times 110 = 1.1 \times 10^{-1} \text{ events per year}$$

Given that the overhead crane bridge and trolley maximum speeds are limited by design, the dose consequences from this scenario would be bounded by the drop of a dry storage container described in Section 5.4.3.1. This event is screened out.

5.4.3.4 Transporter Collision with a Loaded Dry Storage Container or another Transporter

Operator error during transporter vehicle operations could result in a collision with a loaded DSC on the Processing Building floor or with another Transporter in the Processing Building. The Transporter collision could occur while it is carrying a loaded or empty DSC.

It is assumed that a maximum 100 lower-fuel-age DSCs are loaded within one year and that the Transporter is used three times to move each DSC within the Processing Building: 1) transfer of a loaded DSC to the DSC Processing Building, 2) transfer of a seal-welded DSC to the paint station within the Phase I site, and 3) transfer the DSC from processing to storage. Therefore, the probability of a Transporter collision with a loaded DSC or with another Transporter in the Processing Building due to operator error would be

$10^{-3} \times 100 \times 3 = 3 \times 10^{-1}$ events per year.

Given that the Transporter's speed is limited by design and that it is equipped with front and rear bumper emergency stops or sensors, the dose consequences from this scenario would be bounded by the drop of a dry storage container described in Section 5.4.3.1. This event is screened out.

5.4.3.5 Equipment Collision with a Loaded Dry Storage Container during Craning

A craning accident due to operator error could result in process equipment colliding with a loaded DSC while suspended from the auxiliary hoist. To calculate the frequency of this event, the following assumptions were made:

- Maximum 100 lower-fuel-age DSCs will be processed within one year;
- A total of four pieces of equipment have the potential to collide with a loaded DSC while suspended from the auxiliary hoist (transfer clamp, lid welding equipment, and vacuum bell jar lid) [1]; and
- With the exception of the transfer clamp, each structure is lifted twice over the DSC (installation and removal), totalling seven lifts per DSC [1].

The total frequency of this event due to operator error is $10^{-3} \times 100 \times 7 = 7 \times 10^{-1}$ events per year.

Given that the overhead crane bridge and trolley maximum speeds are limited by design, the dose consequences from this scenario would be bounded by the drop of a dry storage container described in Section 5.4.3.1. This event is screened out.

5.4.3.6 Dry Storage Container Processing Building Fire

The DSC Processing Building is a non-combustible building with a reinforced slab-on-grade, steel frame structure, concrete on metal deck floors, concrete block interior walls and, insulated precast concrete panel and insulated metal cladding panel exterior walls. The roof consists of a built-up insulated roof on metal deck on the steel structure [21].

The DSC Processing Building has been designed in accordance with the National Building Code of Canada (NBCC) and the National Fire Code of Canada (NFCC).

Based on the PWMF fire hazard assessment (FHA) [21], the bounding fire scenario for the Processing Building was a fire involving one GEN IV DSC Transporter in the workshop. The safe separation distances between the transporter and combustible materials and transient work equipment (forklift and floor polishers) was assessed and it was determined that the combustible materials would be within the 5.3 m horizontal safe separation distance. As a result, a DSC Transporter fire would likely ignite the adjacent combustibles located in the workshop.

To evaluate the design basis fire event, the quantitative analysis was performed as a worst-case scenario without crediting any fire mitigation systems. After that, the fire scenario was assessed crediting the available fire detection and suppression systems and fire-fighting. The FHA determined that the Emergency Response Team (ERT) would provide suppression within 23 minutes after ignition and the fire would be ended within 30 minutes from ignition. The fire scenarios were used to calculate the impact of the design basis fire on the DSC, structural steel trusses and adjacent DSC transporters.

It was concluded, that due to the fire detection and alarm systems in place in the Processing Building, and the expected prompt arrival of the ERT, the fire would be of short duration and localized.

It is to be noted that no thermal analysis was conducted to investigate the effects of an external fire on the DSC containing 6 year decayed used fuel; however a thermal analysis was conducted to investigate the heating and cooling process of a DSC storing 10 year decayed used fuel during and after a fire under an accident transportation scenario; the DSC is on the Transporter, located in the fire [21]. The thermal assessment concluded that given the large thermal inertia of the DSC and the limited duration of the event, a fire scenario in the Processing Building involving a DSC would not breach the containment and will not result in radiological release. This event is screened out.

5.4.3.7 Earthquake

The DSC Processing Building has been designed to NBCC-1990 seismic requirements; it would not be expected to collapse in the event of an earthquake with a ground motion equal to or smaller than 0.05g.

An analysis was performed to determine the impact of a collapsing DSC Processing Building on an unclamped and un-welded DSC lid for the WWMF Processing Building [30]. It was concluded that the flange of the DSC base interfacing with the lid may experience some permanent damage allowing some airborne release. However, there is no likelihood of the fuel to be exposed based on the magnitude of lid slippage or DSC tipping. The impact of the PWMF Processing Building collapse on an unclamped and un-welded DSC lid is bounded by the collapse of the WWMF Processing Building scenario [31].

The DSC has a safety factor of 7 against overturning and 4 against sliding under the loads described for the earthquake scenario using the Pickering B design basis earthquake (DBE) of 10^{-3} event per year and ground motion parameters of 0.05g PGA [23]. The structure of the container is adequately strong to ensure the integrity of the DSC in case of an earthquake with the above parameters.

Calculations were performed [32] assessing the DSC seismic stability for the lower probability (10^{-4} per year) Pickering A DBE ground motion parameters of 0.12g horizontal PGA and 0.08g vertical PGA. These parameters bound both the Pickering B DBE and the NBCC ground motion parameters for the Pickering site. The calculations revealed that the safety factor against overturning of the DSC is 3 and the safety factor against sliding is 1.54 [32]. While the safety factors are lower than the ones for the Pickering B DBE, in both cases they are greater than 1, meaning that the DSC will not overturn or slide during an earthquake scenario using the more stringent Pickering A DBE. The lower safety factors for Pickering A DBE are acceptable as the probability of the ground motion is lower as well.

However, the hazard for the DSC overturning or tipping under the loads described for an earthquake scenario is bounded by the case when the Processing Building collapses.

An earthquake causing the Processing Building to collapse on an unclamped and un-welded DSC is screened in.

5.4.3.8 Tornado

The effect of tornado-generated missiles on a clamped DSC has been considered in Section 5.4.2.7 and it was concluded that the DSC's transfer clamp will keep the lid in place, the containment will not be breached, and the DSC will not overturn under the impact of the postulated tornado missiles.

It has been postulated that the Processing Building is subject to a tornado at the time that an unclamped DSC stands in preparation of seal-welding, and that an unclamped DSC is struck by a tornado-generated missile.

A DSC can resist overturning in tornado winds of up to 425 km/h [23].This scenario considers the DSC to be subject to the full force of the horizontal wind and ignores the interceding building structures. Therefore, a missile striking the DSC is expected to have negligible consequences, even if the DSC is un-welded.

This event is screened out.

5.4.3.9 Thunderstorms

Thunderstorms can potentially involve lightning striking the DSC Processing Building. Based on the design requirements [18], the DSC was designed to maintain its structural integrity, appropriate shielding and containment function for severe atmospheric conditions, during storage. As severe atmospheric conditions are within the design basis of the DSC, this event is screened out.

5.4.3.10 Flood

Water entry originating from a PMP into the Processing Building is possible, however, the consequences are assumed to be negligible. The expected flood water depth is too shallow to reach near the level of the DSC lid at approximately 2.5 m height [33]. In addition, no loose contamination is permitted on the exterior surface of the DSC or on accessible surfaces within the Processing Building. This event is screened out.

5.4.3.11 Turbine Missile Strike

Phase I of the PWMF is located southeast of PNGS Unit 8. SB2 is situated the closest, at approximately 30 m, to Unit 8. SB2 is attached to the north wall of the Processing Building and SB1.

The frequency of turbine missiles impacting SSCs has been determined in Section 6.2.1 of [28] to be 6×10^{-6} events/year. Given the location of the DSC Processing Building with reference to the Unit 8 turbine, a turbine missile striking the Processing Building and then the DSC is considered to be an incredible event. Therefore, this event is screened out.

5.4.3.12 Aircraft Crash

The probability of an aircraft strike is proportional to the target area. The aircraft crash frequency calculated for the Phase I site, which comprises of the Processing Building, SB1 and SB2, is 2.42×10^{-7} events/year, which is below the cut-off frequency of 10^{-6}, therefore this event is screened out.

In addition, a total aircraft crash frequency was calculated for the PWMF site where DSCs and DSMs are stored and it is presented in Appendix C.

5.4.3.13 Release of Oxidizing, Toxic, Corrosive Liquids Stored in the Processing Building

For a chemical release to have an impact on nuclear safety, the chemical must fall into one of the following categories under Part IV of the Canadian Controlled Products Regulations, as stated in Reference [3]:

- Acute Toxicity
- Corrosive
- Oxidizing/Reactive
- Asphyxiant

The first step to screening the hazard from chemicals held within the PWMF Processing Building is to compile a list of chemicals held in each area. A preliminary screening was made based on whether the chemical falls into any of the above categories. Chemicals not included in the above four categories were screened out.

A secondary screening, based on quantities held on-site could not be performed as quantities are required to be shown on the HazMat Inventory sheets only for flammable liquids. Therefore, toxic materials stored in the Processing Building and SB3 are listed in Table 5-8 without quantities.

5.4.3.13.1 Toxic Materials

Table 5-8 describes the inhalation consequences of the toxic materials. Direct exposure to highly toxic chemicals may cause an operator to become incapacitated, leading to container mishandling errors.

The Material Safety Data Sheet (MSDS) of these chemicals revealed that most of them are minimally toxic when inhaled based on component assessment or based on test data for structurally similar materials. The only exception is the HYVOLT II transformer oil, which, based on its MSDS can be fatal if it enters the airways.

Strict safety procedures and processes are in place for storage and handling of the hazardous chemicals within the Processing Building. The handling of hazardous materials must meet provincial legislation, particularly the Occupational Health and Safety Act and the Environmental Protection Act.

This event is bounded by the drop of a dry storage container described in Section 5.4.3.1 and it is screened out.

5.4.3.13.2 Asphyxiants

Some hazardous chemicals can be used within the PWMF Processing Building as part of normal operations. Table 5-8 shows the chemicals that are stored in the Processing Building's gas bottle storage room and in the workshop [3]. These materials, such as helium and welding cover gas are considered asphyxiants and may lead to container mishandling caused by human error.

However, strict safety procedures and processes are in place for storage and handling of the hazardous chemicals within the Processing Building. The handling of hazardous materials must meet provincial legislation, particularly the Occupational Health and Safety Act and the Environmental Protection Act.

This event is bounded by the drop of a dry storage container described in Section 5.4.3.1 and it is screened out.

Table 5-8 Hazardous Chemicals Stored in Processing Building and SB3

Hazardous Material	CAT ID	Toxic	Oxidizing/ Reactive	Asphyxiant	Quantity/Location	Remarks
Antifreeze, Coolant Ethylene Glycol	328179	X			Location: PWMF, Processing Building, Room 110, Cabinet 33.	Inhalation of ethylene glycol will cause irritation of the eye and respiratory tract, but it is unlikely to result in toxicity. Extremely dangerous in case of ingestion, refer to Material Safety Data Sheet (MSDS).
Silica Gel	473059	X			Location: PWMF, Processing Building, Room 110, Cabinet 36	No acute toxicity information is available for this product, refer to the MSDS. If inhaled, it may cause allergy or asthma symptoms or breathing difficulties.
SIKADUR 32 PART A-B	31222	X			Location: PWMF, Processing Building, Room 110, Cabinet 33	No acute toxicity information is available for this product, Skin and eye irritation
SIKATOP 123 PLUS	634398				Location: PWMF, Processing Building, Room 110, Cabinet 33	May cause skin irritation.

Hazardous Material	CAT ID	Toxic	Oxidizing/ Reactive	Asphyxiant	Quantity/Location	Remarks
Hydraulic Fluid, NUTO H-C 68	323268	X			Location: PWMF, Processing Building, Room 110, Cabinet 36	Inhalation: Acute Toxicity: Based on assessment of the components it is minimally toxic. Irritation: Negligible hazard at ambient/normal handling temperatures, refer to MSDS.
Transformer Oil, Insulating, HYVOLT II	685854	X			Location: PWMF, Storage Building 3, Cabinet 10100	Inhalation: May be fatal if swallowed and enters airways, refer to the MSDS.
Oil, Synthetic Hydro Carbon, Mobil SHC-632	462010	X			Location: PWMF, Processing Building, Room 110, Cabinet 36	Inhalation: Acute Toxicity: Minimally Toxic based on component assessment. Irritation: Negligible hazard at ambient/normal handling temperatures, refer to MSDS.
OIL, VACUUM PUMP P-150	658772				Location: PWMF, Processing Building, Room 110, Cabinet 36	Acute Toxicity: Respiratory tract irritation refer to MSDS.

Hazardous Material	CAT ID	Toxic	Oxidizing/ Reactive	Asphyxiant	Quantity/Location	Remarks
OIL, INDUSTRIAL STEAM TURBINE, TERESTIC-C100	323231	X			Location: PWMF, Processing Building, Room 110, Cabinet 36	Acute Toxicity: Minimally Toxic based on component assessment, refer to the MSDS Irritation: Negligible hazard at ambient/normal handling temperatures.
OIL, GEAR, SPARTAN EP220	323285	X			Location: PWMF, Processing Building, Room 110, Cabinet 36	Acute Toxicity: Minimally Toxic based on component assessment, refer to the MSDS Irritation: Negligible hazard at ambient/normal handling temperatures.
Mobile Delvac 1300 Super 15W30 Engine Oil	670659	X			Location: PWMF, Storage Building 3, Cabinet 10100	MSDS for Mobile Delvac 1300 Super 15W30 has not been located. *MSDS for Engine Oil, DELVAC, 15W40*: Inhalation: Acute Toxicity: Minimally Toxic based on test data for structurally similar materials. *MSDS for Engine Oil, DELVAC, 10W30*: Inhalation: Acute Toxicity: Minimally Toxic based on assessment of components.

Hazardous Material	CAT ID	Toxic	Oxidizing/ Reactive	Asphyxiant	Quantity/Location	Remarks
ENGINE OIL, MOBIL DELVAC, 1300 SUPER 15W40 SZE, CJ-4 API	670659	X			Location: PWMF, Storage Building 3, Cabinet 10100	Inhalation: Acute Toxicity: Minimally Toxic based on test data for structurally similar materials.
HYDRAULIC FLUID, NUTO H-C 32	323228	X			Location: PWMF, Processing Building, Room 110, Cabinet 36	Inhalation: Acute Toxicity: Based on assessment of the components it is minimally toxic.
THREADLOCK ADHESIVE, LOCTITE 242	329117	X			Location: PWMF, Storage Building 3, Cabinet 10100	Inhalation of vapors or mists may be irritating to the respiratory system. Skin and eye irritation

Hazardous Material	CAT ID	Toxic	Oxidizing/ Reactive	Asphyxiant	Quantity/Location	Remarks
Welding cover gas (92% Argon + 8% Carbon Dioxide)				X	Stored in the gas bottle storage room, Processing Building. This room is located in the northwest corner of the workshop and is only accessible from the outside.	Acute exposure to welding fume and gases can result in eye, nose and throat irritation, dizziness and nausea. However, PWMF technicians operate the weld machine remotely from the welding control room. Both the Workshop (Room 117) and the Welding Platform (Room 211) have active ventilation to avoid accumulation of fume and gas levels.
Helium				X	Stored in the gas bottle storage room, Processing Building. This room is located in the northwest corner of the workshop and is only accessible from the outside.	Helium bottles are stored in a separate room. Strict safety procedures and processes are in place for storage and handling of the hazardous chemicals.

5.4.4 Malfunctions/Accidents during DSC Storage

5.4.4.1 Dry Storage Container Seal Weld Failure during Storage

Both the fuel sheath and the DSC lid seal-weld must fail for a release of radionuclides to occur. Used fuel having a known damaged or defective sheath is not loaded into a DSC. Failure of the sheath is not expected to occur during the operating life of the storage facility. The lid closure weld is a groove weld between the base plate of the lid and the perimeter flange of the base. After the weld has been completed and cooled, a PAUT system is used for the inspection of the DSC lid-to-base seal-weld. The DSC is subsequently filled with inert helium and leak tested prior to storage.

As the seal-welds are inspected and pressure tested, and there is no external force acting upon the DSCs during storage, it is concluded that random weld failures are not a credible event. This event is screened out.

5.4.4.2 Dry Storage Container Drop during Transfer to Storage

It is assumed that 119 existing DSCs stored in SB3 will be moved to the adjacent SB4 in order to accommodate the newly transferred 100 lower-fuel-age DSCs in SB3. Then 19 DSCs will be moved back from SB4 to SB3 and placed between the lower-fuel-age DSCs and the aisle, see Figure 5-2. It is further assumed, that the 238 (119+100+19) DSC movements in SB3 and between SB3 and SB4 will be performed within one year.

Failure of the Transporter or the DSC lift plates while the DSC is lifted by the Transporter during transfer to placement of a loaded DSC within the Phase II storage buildings, SB3 and SB4, could result in a DSC drop. This scenario is unlikely given the independent mechanical locking mechanism on each side of the Transporter to prevent DSC drop. Failure of one independent mechanical locking mechanism is 1.0×10^{-4} events/year [1].

The postulated frequency of both mechanical locking mechanisms failing simultaneously, while carrying a loaded DSC within the Phase II storage buildings would be:

$$(1.0 \times 10^{-4}) \times (1.0 \times 10^{-4}) \times 238 = 2.38 \times 10^{-6} \text{ events per year}$$

This value is greater than the cut-off frequency of 10^{-6} events per year.

Given that the Transporter is equipped with front and rear bumper emergency stops or sensors, and taking into account the low-lift height of the DSC while in the Transporter and that the loaded DSC has been seal-welded at this stage of the process, no releases would result from this scenario [1]. This event is screened out.

5.4.4.3 Transporter Collision with a Dry Storage Container or another Transporter

Operator error during the Transporter operations could result in a collision with a loaded DSC on the floor of the SB3 or with another Transporter within SB3.

It is assumed that a maximum of 100 lower-fuel-age DSCs are transferred to SB3 and 119 existing DSCs are re-arranged/moved to accommodate the newly arrived lower-fuel-age DSCs resulting in 238 DSC movements as discussed in Section 5.4.4.2. The 238 movements are assumed to be performed within a single year. The postulated frequency of a DSC drop or collision event within the DSC storage building due to operator error (10^{-3} per movement) would be:

$$10^{-3} \times 238 = 2.38 \times 10^{-1} \text{ events/year.}$$

This event cannot be screened out based on frequency. However, given that the Transporter is equipped with front and rear bumper emergency stops or sensors, the low lift height of the DSC while in the Transporter and that the loaded DSC has already been seal-welded at this stage of the process, no releases would result from this scenario [1]. There would be no public or occupational dose consequences as a result of this event. This event is screened out.

5.4.4.4 DSC Storage Building 3 Fire

Storage Building 3 is of non-combustible construction with a reinforced slab-on-grade, steel structure, and concrete exterior walls. The bounding fire scenario for both Phase I and Phase II storage buildings is a fire involving one DSC Transporter, with two transporters located in the storage building [21]. The design basis fire scenario postulated an oil spill and a rubber tire fire without any fire mitigation measures.

The safe separation distances between the transporter involved in the fire and other targets/transient materials was assessed and it was determined that the combustible materials in Storage Building 3 were located outside the 5.3 m horizontal safe separation distance from the DSC Transporter parking area. As a result, transient materials located along the SB3 walls were not expected to be affected by a Transporter fire.

For the design basis fire, the quantitative analysis was performed without crediting the fire detection and suppression systems. Then the fire scenario was assessed crediting the available fire detection, suppression and fire-fighting. The FHA determined that the Emergency Response Team would provide suppression within 23 minutes after ignition and the fire would be ended within 30 minutes from ignition. The fire scenarios were used to calculate the impact of the design basis fire on the DSC, structural steel trusses and adjacent DSC transporters.

Due to the fire detection and alarm systems in place in all three storage buildings, and the expected prompt arrival of the emergency response personnel, the fire would be of short duration and localized.

The effects of a fire could potentially increase the temperature of the DSC and the used fuel bundles inside the container. It is to be noted that no thermal analysis was conducted to investigate the effects of an external fire on the DSC containing 6 year decayed used fuel; however a thermal analysis was conducted to investigate the heating and cooling process of a DSC storing 10 year decayed used fuel during and after a fire with the DSC on the Transporter, refer to Section E4.5.3 of Reference [21]. It was assumed that the DSC was subjected to a steady state of 800°C fire for 30 minutes and then cooled naturally for 48 hours. A very slow and gradual rise of the fluid temperature in the DSC cavity was experienced after the cessation of the fire. It was found that the maximum fuel sheath temperature will rise to 143°C, and the maximum internal pressure would be 99.47 kPa(a), with the maximum temperature rise of 17.13°C. As previously noted, no specific fire scenario for the 6 year decayed used fuel has been performed, however it can be concluded that a similar temperature rise could be expected considering a similar fire scenario and DSC design characteristics.

Section 5.5 details the fuel sheath temperature of the 6 year decayed used fuel was predicted to be between 175°C and 265°C[18], depending on the operating pressure in the DSC cavity. Based on the maximum 6 year decayed used fuel sheath temperature predictions and the fire-induced temperature increase it is expected that the maximum temperature rise in the DSC cavity to be less than the maximum allowed sheath temperature of 300°C.

Given the large thermal inertia of the DSC and the limited duration of the event, the fire scenario involving a DSC within SB3 would not breach the containment and will not result in radioactive emissions or radiological release. This hazard is therefore screened out.

5.4.4.5 Tornado

A DSC can resist overturning in tornadoes with winds of up to 425 km/h [23]. This scenario considers the DSC to be subject to the full force of the horizontal wind and ignores the storage building structures.

The effect of tornado missiles has been evaluated on a clamped DSC and it was concluded that the transfer clamp will keep the lid in place, the containment will not be breached, and the DSC will not overturn under the impact of postulated tornado missiles [3]. It is also expected that the wind associated with a DBT will not overturn a DSC loaded with used fuel, which has a safety factor greater than 5 against overturning due to tornado winds [3]. Based on these findings, it can be concluded that a seal-welded DSC will not overturn under the impact of postulated tornado missiles/ severe wind load and the containment will not be breached as a result of a tornado-generated missiles.

Based on the design requirements [18], the DSC, while in storage, will withstand tornado generated missile impacts, strong winds and storage building structural failure or collapse without loss of shielding or containment. Therefore, it is expected that a tornado would result in no releases from DSC in storage and there would be no public or occupational dose consequences. This event is screened out.

5.4.4.6 Thunderstorms

Thunderstorms can potentially involve lightning striking the DSC storage building.

Based on the design requirements [18], the DSC was designed to maintain its structural integrity, appropriate shielding and containment function for severe atmospheric conditions, during storage. As severe atmospheric conditions are within the design basis of the DSC, this event is screened out.

5.4.4.7 Flooding due to Runoff

Water entry originating from a PMP into SB3 is possible, however, the consequences are assumed to be negligible. The DSCs are seal-welded and they are designed to tolerate water immersion at 2 MPa [18], so the temporary waters of the PMP flooding does not represent radiological safety concern. This event is screened out.

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18 The 265°C corresponds to 0.01 kPa(a) (vacuum pressure). The DSC is not stored under total vacuum, therefore it is unlikely that the fuel sheath's temperature will be 265°C during storage.

5.4.4.8 Earthquake

The DSC has a safety factor of 7 against overturning and 4 against sliding under the loads described for the earthquake scenario using the Pickering 'B' seismic ground response spectra and accelerations of 0.0625g horizontal and 0.05g vertical PGA [23]. The structure of the container is adequately strong to ensure the integrity of the DSC in case of an earthquake with the above parameters.

The DSC, by design is required to withstand a storage building collapse without loss of shielding or containment [18].

It can be concluded that an earthquake would result in no releases from the seal-welded DSCs stored in SB3 and there would be no public or occupational dose consequences. This event is screened out.

5.4.4.9 Toxic Materials stored in Storage Building 3

Table 5-8 shows that the only toxic chemical stored in Storage Building 3 that can be fatal if enters the airways based on its MSDS is the HYVOLT II transformer oil. Inhalation of acute toxicity chemicals can lead to container mishandling caused by human error.

Strict safety procedures and processes are in place for storage and handling of the hazardous chemicals within the Processing Building. The handling of hazardous materials must meet provincial legislation, particularly the Occupational Health and Safety Act and the Environmental Protection Act.

The Transporter operates at a low speed within the SB3. Even if operator illness were to result in the Transporter collision with a container in storage, a release of radioactivity from a DSC is not expected given the design of the DSC and that the container has already been seal-welded at this stage of the process. This event is screened out.

5.4.4.10 Aircraft Crash

The probability of an aircraft strike is proportional to the target area. The aircraft crash frequency calculated for the Phase II site, which includes Storage Buildings SB3 and SB4, is 2.92×10^{-7} events/year, which is below the cut-off frequency of 10^{-6}, therefore this event is screened out.

In addition, a total aircraft crash frequency was calculated for the PWMF where DSCs and DSMs are stored/processed and it is presented in Appendix C.

5.4.5 Bounding Scenarios

5.4.5.1 DSC during Transport

There are two events related to DSC on-site transfer that have been screened in:

- Transporter failure during on-site transfer of the DSC between the station IFB to the Processing Building
- Drop of the DSC

For the transporter failure, release from four damaged fuel elements is assumed as a result of the event, whereas for the DSC drop, 100% of the fuel is assumed failed in both scenarios. Therefore, the DSC drop is deemed to be the bounding credible scenario.

5.4.5.2 DSC Bounding Event during Processing

There are two events related to DSC processing that have been screened in:

- DSC drop
- Earthquake

For the DSC drop scenario it is assumed that 30% of the fuel fails and the containment is impaired.

For the earthquake scenario, it is postulated that the processing building collapses onto an unclamped and un-welded DSC, without the fuel being exposed, but lid damage can result in some airborne release.

The impact force to the fuel is considered larger when the loaded DSC is dropped compared to the case where an object falls onto the DSC. Based on the radiological consequences, the DSC drop is assessed to be the bounding credible scenario.

5.4.5.3 DSC during Storage

All of the events related to DSC storage were screened out and therefore there is no bounding scenario.

5.4.6 Inventory and Releases

The PWMF UFDS facility stores used fuel bundles from the PNGS. The PNGS use 28-element CANDU fuel bundles. Approximately 3000 fuel bundles are discharged each year from each of the reactors at PNGS [1]. After a minimum of 6 years of cooling in the Pickering irradiated fuel bays, fuel bundles may be transferred to DSCs for interim dry storage.

For the purpose of future operation of the PWMF, the current safety assessment considers the storage of up to 100 DSCs containing 6 year decayed used fuel. The description of a used fuel bundle is given in Table 4-1.

Under normal operating conditions, no significant airborne emissions are expected from the DSCs because the uranium dioxide matrix, the used fuel sheath, and the seal-weld provide multiple barriers towards preventing the release of radioactive materials. While no significant releases are expected from DSCs under normal operating conditions, small quantities of fixed surface contamination may become airborne during welding operations [1].

In the event that a used fuel bundle should become damaged during PWMF operations, the only significant radionuclide species that are volatile and available for release are tritium, carbon-14, and krypton-85. For a fuel element damaged under abnormal operating conditions, it is postulated that the free inventory of tritium, carbon-14, and krypton-85 is the radionuclide inventory in the gap between the fuel matrix and the Zircaloy sheath plus 10 percent of the inventory in the grain boundary. The free inventory is released following a postulated malfunction and accident scenario.

For a fuel bundle which has cooled for a period of 6 years, the releases per failed fuel element are listed in Table 5-9.

The bounding scenario (see Section 5.4.5) for the DSC storage in SB3 is the drop of a DSC during transfer, which conservatively assumes to result in all (10,752) fuel elements in the DSC to fail.

Table 5-9: Activity Released per Failed Fuel Element

Nuclide	**Bq released per failed fuel element**
Krypton-85	1.10E+09
Tritium (HTO)	1.79E+08
Carbon-14	1.46E+04
Note: The Bq released was calculated based on the following values: + Fraction of inventory in gap = 0.0095 + Fraction of inventory in grain boundary = 0.123 + Percent of gap inventory being released = 100% + Percent of grain boundary inventory being released = 10%	

5.4.7 Public Dose

The bounding scenario identified in Section 5.4.5 for dose consequence to the public is the DSC drop which conservatively assumes to result in all (10,752) fuel elements in the DSC to fail. Using the ADDAM code (see Appendix D) the 95th percentile doses were calculated for the scenario where the DSC drop occurs near Phase I or Phase II and are summarized in Table 5-10.[19] The 95th percentile individual dose following the limiting malfunction / accident scenario is:

Release from the Phase I site:

- 6.02E-03 mSv (adult), which is 0.60% of the 1 mSv dose limit.
- 7.28E-03 mSv (infant), which is 0.73% of the 1 mSv dose limit.

The limiting 95th percentile doses occur at the lakeside boundary where the fishermen are assumed to be located.

Release from the Phase II site:

- 7.38E-03 mSv (adult), which is 0.74% of the 1 mSv dose limit.
- 9.00E-03 mSv (infant), which is 0.90% of the 1 mSv dose limit.

The limiting 95th percentile doses occur at the East landside boundary (receptor B_E in Figure 5-5).

[19] The ADDAM input files (Phase I and Phase II sites, without buildings) used in the analysis documented in Reference [3] were used as input for the current calculations. All meteorological data, radionuclide data, and site descriptions in the input files remain unchanged from the analysis in Reference [3]; the release source term was updated as per Section 5.4.6.

Table 5-11 shows the public and occupational dose consequences due to those malfunctions and accidents deemed credible (i.e., events with frequency of occurrence ≥10^{-6} events per year) during DSC on-site transfer.

The bounding dose consequences during this stage of the dry storage process are associated with the drop of a DSC during on-site transfer. Although fuel sheath failure is not expected to result from a DSC drop from the low lift height of the Transporter, the drop of a DSC during on-site transfer was conservatively assumed to result in 100 percent failure of the fuel elements inside a DSC. Consequently, the free inventory from 10,752 failed fuel elements is assumed to be released. The free inventory of tritium, krypton-85, and carbon-14 in the damaged fuel elements is assumed to be released into the DSC cavity. Ignoring that DSCs being transferred from the PWMF Phase I site to the PWMF Phase II site are already seal-welded, it is assumed that these radionuclides are released at once into the environment.

Assuming that this event occurs at or near the PWMF Phase II site, the limiting individual dose to the public (95th percentile) was calculated to be 7.38 µSv for an adult and 9.00 µSv for an infant at the Pickering site boundary [3]. The dose to a NEW would be 5.92 mSv (see Section 5.4.8). Table 5-12 shows the public and occupational dose consequences for postulated malfunctions / accidents which occur during DSC processing. The dose consequence for DSCs during storage in SB3 is shown in Table 5-13.

Table 5-10: 95th Percentile Public Dose following the Limiting Malfunction Accident Scenario

	Phase I		Phase II	
Location	**Adult (µSv)**	**Infant (µSv)**	**Adult (µSv)**	**Infant (µSv)**
B_N	0.00	0.00	0.00	0.00
B_NNE	0.33	0.40	0.47	0.57
B_NE	0.42	0.54	1.22	1.47
B_ENE	0.27	0.32	1.37	1.66
B_E	1.18	1.41	7.38	9.00
B_ESE-Lake	1.35	1.56	1.32	1.43
B_SE-Lake	2.57	3.58	1.11	1.34
B_SSE-Lake	1.78	2.13	0.46	0.57
B_S-Lake	5.72	6.93	1.52	1.83
B_SSW-Lake	0.68	0.94	0.34	0.36
B_SW-Lake	0.00	0.00	0.00	0.00
B_WSW-Lake	0.00	0.00	0.00	0.00
B_W-Lake	0.10	0.12	0.07	0.08
B_WNW	0.00	0.00	0.00	0.00
B_NW	0.00	0.00	0.00	0.00
B_NNW	0.00	0.00	0.00	0.00
IND	0.30	0.36	0.53	0.63
Fisher	6.02	7.28	1.48	1.79
Beach	0.00	0.00	0.00	0.00
UR_WNW	0.00	0.00	0.00	0.00
UR_NW	0.00	0.00	0.00	0.00
UR_NNW	0.00	0.00	0.00	0.00
C2	0.07	0.08	0.09	0.11
Dairy Farm	0.02	0.02	0.02	0.02
Farm	0.03	0.03	0.03	0.04
Ajax WSP	0.05	0.06	0.05	0.06
Max. Dose on Landside	1.18	1.41	7.38	9.00
Location	B_E	B_E	B_E	B_E
Max. Dose on Lake	6.02	7.28	1.52	1.83
Location	Fisher	Fisher	B_S-Lake	B_S-Lake

Notes:
Doses shown correspond to the most limiting accident scenario at PWMF, which is a DSC event during transfer resulting in 100% failed fuel elements inside the DSC.

Table 5-11: Postulated Malfunctions / Accidents during DSC On-Site Transfer

Malfunction or accident	Potential for occurrence	Potential maximum dose consequence to the public (mSv)		Potential maximum individual occupational dose consequence (mSv)
		Adult	Infant	
Transporter failure between the station IFB and Processing Building	Credible	<6.02E-03	<7.28E-03	<5.9
Transporter failure between Processing Building and SB3	Credible	<6.02E-03	<7.28E-03	<5.9
Transporter operator health-related emergency	Credible	<6.02E-03	<7.28E-03	<5.9
DSC drop during on-site transfer from IFB to DSC Processing Building	Credible	6.02E-03	7.28E-03	5.9
DSC drop during on-site transfer from Phase I to Phase II site	Credible	7.38E-03	9.00E-03	5.9
Fire	Credible	0	0	0
Adverse road conditions	Credible	<7.38E-03	<9.00E-03	<5.9
Earthquake[a]	Credible	<7.38E-03	<9.00E-03	<5.9
Tornado[a]	Incredible[b]	-	-	-
Thunderstorms[a]	Credible	0	0	0
Flooding[a]	Credible	0	0	0
Explosions along transfer route	Incredible	-	-	-
Turbine missile strike	Incredible	-	-	-
Aircraft crash	Incredible	-	-	-
Toxic gas releases – chlorine from Ajax water treatment plant	Credible	<7.38E-03	<9.00E-03	<5.9
Soil failure/slope instability	Credible	<7.38E-03	<9.00E-03	<5.9

Notes:

a) For common cause events, the potential maximum dose consequence as reported is related to DSC on-site transfer only and does not include contribution from other sources on site.

b) The term incredible is used for those events with frequency of occurrence below 10^{-6} events per year.

Table 5-12: Postulated Malfunctions / Accidents during DSC Processing

Malfunction or accident	Potential for occurrence	Potential maximum dose consequence to the public (mSv)		Potential maximum individual occupational dose consequence (mSv)
		Adult	Infant	
Drop of a DSC during handling	Credible	<6.02E-03	<7.28E-03	<5.9
Equipment drop onto a DSC	Credible	<6.02E-03	<7.28E-03	<5.9
DSC collision during craning	Credible	<6.02E-03	<7.28E-03	<5.9
Transporter collision with a loaded DSC or other transporter	Credible	<6.02E-03	<7.28E-03	<5.9
Equipment collision with loaded DSC during craning	Credible	<6.02E-03	<7.28E-03	<5.9
Processing Building Fire	Credible	0	0	0
Earthquake[a]	Credible	0	0	0
Tornado[a]	Incredible[b]	-	-	-
Thunderstorms[a]	Credible	0	0	0
Flooding[a]	Credible	0	0	0
Turbine missile strike	Incredible	-	-	-
Aircraft crash	Incredible	-	-	-
Release of oxidizing, toxic, corrosive liquids stored in the PB	Credible	<6.02E-03	<7.28E-03	<5.9

Notes:
a) For common cause events, the potential maximum dose consequence as reported is related to DSC processing only and does not include contribution from other sources on site.
b) The term incredible is used for those events with frequency of occurrence below 10^{-6} events per year.

Table 5-13: Postulated Malfunctions/Accidents during DSC Storage in SB3

Malfunction or accident	Potential for occurrence	Potential maximum dose consequence to the public (mSv)		Potential maximum individual occupational dose consequence (mSv)
		Adult	Infant	
Seal weld failure during storage	Incredible[a]	-	-	-
DSC drop during transfer to storage	Credible	<7.38E-03	<9.00E-03	<5.9
Transporter collision with a DSC or another transporter	Credible	<7.38E-03	<9.00E-03	<5.9
Fire	Credible	0	0	0
Tornado[b]	Credible	0	0	0
Thunderstorms[b]	Credible	0	0	0
Flooding[b]	Credible	0	0	0
Earthquake[b]	Credible	<7.38E-03	<9.00E-03	<5.9
Toxic Materials in SB3	Credible	<7.38E-03	<9.00E-03	<5.9
Aircraft Crash	Incredible	-	-	-

Notes:
a) The term incredible is used for those events with frequency of occurrence below 10^{-6} events per year.
b) For common cause events, the potential maximum dose consequence as reported is related to DSC storage in SB3 only and does not include contribution from other sources on site.

5.4.8 Worker Dose

The worker is assumed to be present in the vicinity of the accident location wearing no protective clothing or respiratory protection at the time of the accident. The worker's response time to leave the accident location under emergency back-out conditions is assumed to be 120 seconds [3]. Normal radiation protection procedures would have the worker leave the building or general area at the time of the accident to allow any airborne particulate levels to subside before any other activities, such as clean-up if needed, can be initiated.

The dose to workers following a postulated accident scenario was calculated by including the contributions from the inhalation and cloudshine exposure pathways. The release and mixing of radionuclides are assumed to be instantaneous.

Dose from inhalation:

$$D_{inhalation} = \sum_{n=1} \left(R_n \times BR \times sk_{a,n} \times DCF_{inhalation,n}\right) \times T/V$$

where:

- $D_{inhalation}$ = worker dose from inhalation (Sv);

- R_n = release amount (Bq) during the exposure time (krypton-85 = 1.10x10^9 Bq, tritium = 1.79x10^8 Bq, and carbon-14 = 1.47x10^4 Bq);
- BR = worker breathing rate (4.17X10^{-4} m^3/s);
- $sk_{a,n}$= skin absorption factor for nuclide n. $sk_{a,n}$=1.5 for tritium and =1 for other nuclides.
- $DCF_{inhalation,n}$ = inhalation dose coefficient (tritium = 1.8x10^{-11}Sv/Bq, carbon-14 = 6.5x10^{-12} Sv/Bq);
- T = exposure time (120 s); and
- V = contaminated cloud volume (500 m^3).

Dose from cloudshine:

$$D_{cloudshine} = \sum_{n=1} \left(R_n \times DCF_{cloudshine,n}\right) \times T/V$$

where:

- $D_{cloudshine}$ = worker dose from cloudshine (krypton-85 = 6.75x10^{-8} Sv, carbon-14 = 9.13x10^{-15} Sv); and
- $DCF_{cloudshine,n}$ = cloudshine dose coefficient krypton-85 = 2.55x10^{-16} Sv.m^3.Bq^{-1}.s^{-1}, carbon-14 = 2.60x10^{-18} Sv.m^3.Bq^{-1}.s^{-1}) .

The dose to the worker following a DSC event during transport scenario where 100% of the fuel elements in the DSC are assumed failed is estimated to be 5.92 mSv, which came from the following contributors[20]:

- 5.19 mSv from inhalation (including skin absorption) of tritium;
- 0.73 mSv from cloudshine of krypton-85.

Carbon-14 releases from the DSC makes an insignificant contribution to the dose (<0.1%).

The calculated worker dose is approximately 12% of the 50 mSv worker dose limit.

5.5 Fuel Sheath Temperature

As identified in Section 2.0, a qualitative assessment of the fuel sheath temperature for 6 year decayed used fuel is provided in this Section. One of the key requirements for the DSC is to maintain a fuel sheath temperature below the allowable maximum fuel sheath temperature under dry storage conditions in a DSC. A detailed discussion of the potential for oxidation of fuel stored in the Pickering DSCs is given in Appendix H of the 1998 issue of the PWMF Safety Report, concluding that when the used fuel is stored in a helium atmosphere, temperatures of up to 300°C can be considered safe for the planned storage period. That is, CANDU fuel can be stored in the Pickering DSCs without rick of fuel sheath temperatures exceeding 300°C.

[20] Groundshine contributions are not applicable for the current scenario since tritium and carbon-14 are beta emitters and krypton-85 does not deposit on the ground.

Two different thermal assessments, estimating the dry storage sheath temperature for the 6 years old used fuel, were previously performed and documented in Appendix A of the 1998 issue of the PWMF Safety Report (92896-SR-01320-10002 R000) and Reference [34]. However, there was a difference of about 100°C between the maximum sheath temperatures predicted in the above two analyses as a result of the different conditions assumed in these assessments.

An independent review of the two previous assessments, including independent Computational Fluid Dynamics simulations using commercial code ANSYS CFX 17.2, was performed and documented in Reference [35].

As discussed in Reference [35], the first assessment documented in Appendix A of the 1998 issue of the PWMF Safety Report was conducted using helium at 145 kPa(a) operating pressure for the DSC cavity and resulted in a maximum sheath temperature prediction of 175°C. On the other hand, the second assessment documented in Reference [34] was conducted using near vacuum (0.01 kPa(a)) which almost eliminated natural convection in the DSC cavity and resulted in a maximum sheath temperature prediction of 265°C. The difference between the temperatures obtained by the two previous thermal assessments was mainly due to the different internal pressures used for their simulations as confirmed by the independent simulations performed in Reference [35].

The calculated fuel sheath temperatures for the storage of 6 year decayed used fuel are found to be less than 300°C even at near vacuum conditions. Therefore, no issues with respect to fuel sheath temperature are expected for the storage of DSCs containing 6 year decayed used fuel.

6.0 CONCLUSIONS

The current report summarizes the safety assessment of the storage of DSCs containing 6 year decayed used fuel in SB3 at the PWMF and any impact on common-mode accidents that impact the entire PWMF site. Dose consequences under normal operation and malfunction/accident conditions were assessed.

The assessment demonstrates compliance with the radiation safety requirements during normal operation of the PWMF when SB3 is in service. With the addition of the 100 DSCs containing 6 year decayed used fuel, the annual public dose estimates have increased compared to that of the existing PWMF configuration. The maximum annual dose to individual member of the public with the addition of these 100 DSCs is still a small percentage of the 1 mSv limit. With respect to malfunction / accident scenarios, the estimated bounding doses to members of the public (see Table 5-10) are less than the 1 mSv acceptance criterion. The dose to workers following a postulated accident scenario is found to be much less than the 50 mSv limit (see Section 5.4.8). It is concluded that the dose consequences to workers and members of the public as a result of credible postulated malfunction / accident scenarios meet the acceptance criteria outlined in Section 5.2.

The review of the fuel sheath temperature did not indicate any concerns with the previously conducted analyses and the fuel sheath temperature is not expected to exceed 300°C. Therefore, there are no issues with respect to fuel sheath temperature expected for the storage of DSCs containing 6 year decayed used fuel.

7.0 REFERENCES

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[3] Ontario Power Generation, “Pickering Waste Management Facility Safety Assessment Update”, 92896-REP-01320-00005 R002, August 2018.

[4] Canadian Standards Association, “General Principles for the Management of Radioactive Waste and Irradiated Fuel”, CSA N292.0-14, May 2014.

[5] Canadian Standard Association, “Guidelines for Calculating Derived Release Limits for Radioactive Material in Airborne and Liquid Effluents for Normal Operation of Nuclear Facilities”, CSA N288.1-14, March 2014.

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8.0 ACRONYMS

AIFB	Auxiliary Irradiated Fuel Bay
ALARA	As Low As Reasonably Achievable
BLEVE	Boiling Liquid Expanding Vapour Explosion
CANDU	CANada Deuterium Uranium
CNSC	Canadian Nuclear Safety Commission
CSA	Canadian Standards Association
DBE	Design Basis Earthquake
DBT	Design Basis Tornado
DNGS	Darlington Nuclear Generating Station
DSC	Dry Storage Container
DSM	Dry Storage Module
ERT	Emergency Response Team
FHA	Fire Hazard Analysis
IFB	Irradiated Fuel Bay
MSDS	Material Safety Datasheet
NBCC	National Building Code of Canada
NEW	Nuclear Energy Worker
NFCC	National Fire Code Canada
NGS	Nuclear Generating Station
OHSA	Occupational Health and Safety Act
OPG	Ontario Power Generation
PAUT	Phased Array Ultrasonic Testing
PB	Processing Building
PBIFB	Pickering B Primary Irradiated Fuel Bay
PGA	Peak Ground Acceleration
PMP	Probable Maximum Precipitation
PNGS	Pickering Nuclear Generating Station
PSA	Probabilistic Safety Assessment
PWMF	Pickering Waste Management Facility
RCS	Retube Components Storage
SB	Storage Building
SDV	Screening Distance Value
SSC	Structure, System, and Component
UFDS	Used Fuel Dry Storage
VCE	Vapour Cloud Explosion
WWMF	Western Waste Management Facility

Appendix A PWMF 6 YEAR DECAYED USED FUEL BUNDLE SOURCE TERM

The radionuclide inventory for the PWMF reference used fuel bundle was generated as part of the work for the Safety Assessment Update (see discussion in Appendix B of Reference [3). The generation of the radionuclide inventory in Reference [3] involved the use of a 28-element Pickering-specific cross-section library and a bundle-wise calculation methodology. The cross-section library has since been revised in Reference [36]. Further, Reference [36] recommends using a ring-wise methodology to determining the radionuclide inventory, where calculations are performed for each ring of the fuel bundle and then summed to obtain the bundle-wise quantities.

There are no significant differences in the radionuclide inventory of tritium, carbon-14, and krypton-85 (the radionuclides of interest with respect to airborne releases following postulated credible accident scenarios involving PWMF DSCs) when calculated using the revised cross-section library compared to the inventory listed in Reference [3]. However, following the recommendation identified in Reference [36] for using the ring-wise calculation methodology, the summed inventory of carbon-14 is decreased. Further discussion is provided in Reference [36].

The revised cross-section library generated in Reference [36] was used to generate the radionuclide inventory for a 28-element Pickering-specific fuel bundle following the ring-wise calculation methodology. The inventory was generated for various decay times using the reference fuel bundle properties [9], these include:

- Pickering-type 28-element fuel bundle;
- Mass of uranium per bundle is 20.2 kg;
- Exit burnup of 230 MWh/kgU; and
- Fuel bundle power of 373 kW (fission) representing the core average of 100% full power operations.

The radionuclide inventories for a PWMF used fuel bundle at reference burnup (230 MWh/kgU) are presented in Table A-1 for a decay time of 6 year. For comparison, the updated 10 year decayed used fuel bundle inventory is included.

Table A-1 PWMF Used Fuel Bundle Radionuclide Inventory

Bq/bundle					
Nuclide	6 Year Decayed	10 Year Decayed	Nuclide	6 Year Decayed	10 Year Decayed
Ac-225	1.61E+00	2.30E+00	Os-185	4.24E+00	8.47E-05
Ac-226	0.00E+00	0.00E+00	Os-186	1.10E-04	1.10E-04
Ac-227	1.39E+02	2.47E+02	Os-189m	0.00E+00	0.00E+00
Ac-228	4.29E-02	5.90E-02	Os-191	0.00E+00	0.00E+00
Ag-105	6.11E-14	0.00E+00	Os-194	8.67E+04	5.46E+04
Ag-106m	0.00E+00	0.00E+00	P-32	1.94E+03	1.90E+03
Ag-108	4.00E+05	3.98E+05	P-33	2.54E-18	0.00E+00
Ag-108m	4.60E+06	4.57E+06	Pa-230	0.00E+00	0.00E+00
Ag-109m	1.07E+07	1.20E+06	Pa-231	9.28E+02	1.15E+03
Ag-110	1.66E+07	2.87E+05	Pa-232	9.09E-02	9.09E-02
Ag-110m	1.22E+09	2.11E+07	Pa-233	2.16E+07	2.20E+07
Ag-111	0.00E+00	0.00E+00	Pa-234	3.95E+05	3.95E+05
Al-26	5.79E+00	5.79E+00	Pa-234m	2.47E+08	2.47E+08
Am-241	2.05E+11	3.04E+11	Pb-202	4.19E-02	4.19E-02
Am-242	3.00E+08	2.94E+08	Pb-204	1.43E-05	1.44E-05
Am-242m	3.02E+08	2.96E+08	Pb-205	2.36E+02	2.36E+02
Am-243	1.04E+09	1.04E+09	Pb-209	1.61E+00	2.30E+00
Am-244	1.95E-06	1.43E-06	Pb-210	5.69E+00	9.08E+00
Am-245	2.44E-05	1.03E-06	Pb-211	1.39E+02	2.47E+02
Am-246m	1.08E-08	1.08E-08	Pb-212	4.00E+05	5.38E+05
Ar-37	5.46E-09	0.00E+00	Pb-214	2.11E+01	4.96E+01
Ar-39	5.24E+07	5.18E+07	Pd-103	0.00E+00	0.00E+00
Ar-42	2.59E+01	2.38E+01	Pd-107	3.00E+07	3.00E+07
As-73	8.80E-04	2.93E-09	Pm-143	7.58E-01	1.66E-02
As-74	0.00E+00	0.00E+00	Pm-144	4.20E+01	2.58E+00
At-217	1.61E+00	2.30E+00	Pm-145	2.56E+06	2.21E+06
At-218	4.21E-03	9.92E-03	Pm-146	4.39E+06	2.66E+06
Au-194	4.60E-04	4.57E-04	Pm-147	1.20E+13	4.17E+12
Au-195	1.54E+00	6.69E-03	Pm-148	2.49E-05	0.00E+00
Au-196	0.00E+00	0.00E+00	Pm-148m	5.15E-04	1.15E-14
Ba-131	0.00E+00	0.00E+00	Po-208	3.86E-01	1.48E-01
Ba-133	2.81E+08	2.15E+08	Po-209	6.83E+01	6.65E+01
Ba-136m	0.00E+00	0.00E+00	Po-210	3.67E+04	3.34E+01
Ba-137m	1.91E+13	1.74E+13	Po-211	3.84E-01	6.82E-01
Ba-140	0.00E+00	0.00E+00	Po-212	2.56E+05	3.45E+05

Bq/bundle					
Nuclide	6 Year Decayed	10 Year Decayed	Nuclide	6 Year Decayed	10 Year Decayed
Be-10	3.71E+03	3.71E+03	Po-213	1.57E+00	2.25E+00
Bi-205	0.00E+00	0.00E+00	Po-214	2.11E+01	4.96E+01
Bi-207	3.97E+03	3.63E+03	Po-215	1.39E+02	2.47E+02
Bi-208	6.38E+02	6.38E+02	Po-216	4.00E+05	5.38E+05
Bi-209	1.35E-06	1.35E-06	Po-218	2.11E+01	4.96E+01
Bi-210	5.69E+00	9.08E+00	Pr-143	0.00E+00	0.00E+00
Bi-210m	3.37E+02	3.37E+02	Pr-144	1.77E+12	5.06E+10
Bi-211	1.39E+02	2.47E+02	Pr-144m	1.69E+10	4.83E+08
Bi-212	4.00E+05	5.38E+05	Pt-188	0.00E+00	0.00E+00
Bi-213	1.61E+00	2.30E+00	Pt-190	2.21E-04	2.21E-04
Bi-214	2.11E+01	4.96E+01	Pt-193	1.31E+08	1.24E+08
Bk-247	4.26E-10	4.26E-10	Pu-236	3.16E+06	1.20E+06
Bk-248	1.95E-06	1.43E-06	Pu-237	2.03E-07	4.67E-17
Bk-249	1.68E+00	7.11E-02	Pu-238	9.92E+10	9.62E+10
Bk-250	1.26E-07	7.88E-09	Pu-239	1.25E+11	1.25E+11
Bk-251	0.00E+00	0.00E+00	Pu-240	2.24E+11	2.24E+11
C-14	4.10E+08	4.09E+08	Pu-241	1.73E+13	1.42E+13
Ca-41	6.07E+06	6.07E+06	Pu-242	3.30E+08	3.30E+08
Ca-45	2.73E+06	5.39E+03	Pu-243	1.69E-01	1.69E-01
Ca-48	5.40E-08	5.40E-08	Pu-244	1.80E+01	1.80E+01
Cd-109	1.07E+07	1.20E+06	Pu-246	1.08E-08	1.08E-08
Cd-113	1.09E-05	1.09E-05	Ra-222	0.00E+00	0.00E+00
Cd-113m	5.82E+07	4.78E+07	Ra-223	1.39E+02	2.47E+02
Cd-115m	3.95E-04	5.31E-14	Ra-224	4.00E+05	5.38E+05
Cd-116	1.29E-07	1.29E-07	Ra-225	1.61E+00	2.30E+00
Ce-139	1.95E+04	1.24E+01	Ra-226	2.11E+01	4.96E+01
Ce-141	3.03E-06	8.94E-20	Ra-228	4.29E-02	5.90E-02
Ce-144	1.77E+12	5.06E+10	Rb-82	0.00E+00	0.00E+00
Cf-248	2.37E-07	1.14E-08	Rb-83	6.85E-02	5.41E-07
Cf-249	5.09E-01	5.09E-01	Rb-84	4.18E-13	0.00E+00
Cf-250	3.60E+00	2.91E+00	Rb-86	0.00E+00	0.00E+00
Cf-251	1.37E-02	1.37E-02	Rb-87	4.16E+03	4.16E+03
Cf-252	5.89E-01	2.06E-01	Re-183	2.07E-06	1.08E-12
Cf-253	0.00E+00	0.00E+00	Re-184	9.83E+00	2.45E-02
Cf-254	4.85E-14	2.50E-21	Re-184m	1.04E+01	2.60E-02
Cl-36	9.96E+06	9.96E+06	Re-186	1.55E+03	1.55E+03
Cm-240	0.00E+00	0.00E+00	Re-186m	1.55E+03	1.55E+03

Bq/bundle					
Nuclide	6 Year Decayed	10 Year Decayed	Nuclide	6 Year Decayed	10 Year Decayed
Cm-241	2.33E-15	0.00E+00	Re-187	3.95E+01	3.95E+01
Cm-242	5.62E+08	2.45E+08	Re-188	3.88E-01	1.93E-07
Cm-243	4.47E+08	4.06E+08	Rh-99	0.00E+00	0.00E+00
Cm-244	3.24E+10	2.78E+10	Rh-101	2.47E+03	1.07E+03
Cm-245	1.06E+06	1.06E+06	Rh-102	2.19E+05	1.70E+04
Cm-246	2.16E+05	2.15E+05	Rh-102m	1.19E+07	5.68E+06
Cm-247	1.69E-01	1.69E-01	Rh-103m	1.02E-02	5.60E-14
Cm-248	1.94E-01	1.94E-01	Rh-106	3.11E+12	2.04E+11
Cm-249	0.00E+00	0.00E+00	Rn-217	1.13E-04	1.61E-04
Cm-250	6.02E-08	6.02E-08	Rn-218	4.21E-06	9.92E-06
Co-56	7.60E-06	1.53E-11	Rn-219	1.39E+02	2.47E+02
Co-57	3.35E+05	8.07E+03	Rn-220	4.00E+05	5.38E+05
Co-58	8.67E+00	5.38E-06	Rn-222	2.11E+01	4.96E+01
Co-60	2.01E+09	1.19E+09	Ru-103	1.03E-02	6.37E-14
Co-60m	3.96E+01	3.96E+01	Ru-106	3.11E+12	2.04E+11
Cr-51	2.02E-12	0.00E+00	S-35	1.33E+03	1.25E-02
Cs-131	0.00E+00	0.00E+00	Sb-120m	0.00E+00	0.00E+00
Cs-132	0.00E+00	0.00E+00	Sb-124	1.08E+00	5.34E-08
Cs-134	1.99E+12	5.19E+11	Sb-125	5.94E+11	2.18E+11
Cs-135	4.01E+07	4.01E+07	Sb-126	8.54E+06	8.54E+06
Cs-136	0.00E+00	0.00E+00	Sb-126m	6.10E+07	6.10E+07
Cs-137	2.02E+13	1.84E+13	Sc-44	7.17E-08	6.85E-08
Dy-154	3.28E-08	3.28E-08	Sc-45m	5.19E+01	1.02E-01
Dy-159	1.45E+02	1.30E-01	Sc-46	1.01E+05	5.71E-01
Er-169	0.00E+00	0.00E+00	Se-75	2.66E+05	5.66E+01
Es-252	4.88E-11	5.71E-12	Se-79	1.54E+07	1.54E+07
Es-253	0.00E+00	0.00E+00	Si-32	1.94E+03	1.90E+03
Es-254	1.21E-07	3.06E-09	Sm-145	4.06E+05	2.07E+04
Es-255	2.11E-21	0.00E+00	Sm-146	1.44E+00	1.48E+00
Eu-147	0.00E+00	0.00E+00	Sm-147	1.43E+03	1.62E+03
Eu-148	1.53E-16	0.00E+00	Sm-148	4.28E-03	4.28E-03
Eu-149	2.33E-06	4.39E-11	Sm-151	4.49E+10	4.36E+10
Eu-150	5.06E+02	4.69E+02	Sn-113	3.85E+05	5.81E+01
Eu-152	6.65E+07	5.41E+07	Sn-117m	0.00E+00	0.00E+00
Eu-154	4.44E+11	3.22E+11	Sn-119m	2.50E+09	7.88E+07
Eu-155	3.14E+11	1.75E+11	Sn-121	4.31E+09	4.04E+09
Eu-156	0.00E+00	0.00E+00	Sn-121m	5.55E+09	5.21E+09

Bq/bundle					
Nuclide	6 Year Decayed	10 Year Decayed	Nuclide	6 Year Decayed	10 Year Decayed
Fe-55	4.44E+10	1.62E+10	Sn-123	5.44E+06	2.14E+03
Fe-59	2.83E-05	3.68E-15	Sn-125	0.00E+00	0.00E+00
Fe-60	3.96E+01	3.96E+01	Sn-126	6.10E+07	6.10E+07
Fr-221	1.61E+00	2.30E+00	Sr-82	0.00E+00	0.00E+00
Fr-223	1.92E+00	3.41E+00	Sr-85	4.26E-04	7.01E-11
Ga-68	6.52E-06	1.55E-07	Sr-89	2.51E+01	4.96E-08
Gd-148	5.94E-07	5.72E-07	Sr-90	1.28E+13	1.16E+13
Gd-149	0.00E+00	0.00E+00	Ta-178	0.00E+00	0.00E+00
Gd-150	1.19E-02	1.19E-02	Ta-179	4.76E+04	1.04E+04
Gd-151	3.35E-01	9.49E-05	Ta-182	5.27E+05	8.00E+02
Gd-152	1.47E-04	1.48E-04	Ta-183	0.00E+00	0.00E+00
Gd-153	2.42E+06	3.58E+04	Tb-157	3.17E+05	3.05E+05
Ge-68	6.52E-06	1.55E-07	Tb-158	8.99E+04	8.85E+04
Ge-71	0.00E+00	0.00E+00	Tb-160	1.08E+02	8.94E-05
Ge-73m	8.80E-04	2.93E-09	Tb-161	0.00E+00	0.00E+00
H-3	2.29E+11	1.83E+11	Tc-95	2.00E-09	0.00E+00
Hf-172	1.23E-01	2.79E-02	Tc-95m	5.08E-08	3.13E-15
Hf-174	6.42E-06	6.42E-06	Tc-97	1.13E+02	1.13E+02
Hf-175	7.48E+00	3.89E-06	Tc-97m	4.05E-02	5.94E-07
Hf-177m	1.35E+03	2.45E+00	Tc-98	2.31E+02	2.31E+02
Hf-181	9.91E-05	4.17E-15	Tc-99	3.20E+09	3.20E+09
Hf-182	7.23E+02	7.23E+02	Te-121	1.96E+02	4.11E-01
Hg-194	4.60E-04	4.57E-04	Te-121m	1.96E+02	4.10E-01
Hg-203	3.54E-05	1.29E-14	Te-123m	2.27E+03	4.65E-01
Hg-206	1.08E-07	1.73E-07	Te-125m	1.46E+11	5.33E+10
Ho-163	1.21E+04	1.21E+04	Te-127	2.00E+06	1.84E+02
Ho-166m	3.90E+05	3.89E+05	Te-127m	2.04E+06	1.88E+02
I-125	8.76E-08	3.45E-15	Te-128	7.16E-06	7.16E-06
I-126	0.00E+00	0.00E+00	Te-129	2.16E-07	0.00E+00
I-129	6.26E+06	6.26E+06	Te-129m	3.42E-07	2.78E-20
I-131	0.00E+00	0.00E+00	Th-226	0.00E+00	0.00E+00
In-113m	3.86E+05	5.81E+01	Th-227	1.37E+02	2.44E+02
In-114	4.61E-04	6.02E-13	Th-228	4.00E+05	5.38E+05
In-114m	4.77E-04	6.23E-13	Th-229	1.61E+00	2.30E+00
In-115	7.38E-03	7.38E-03	Th-230	1.30E+04	2.00E+04
In-115m	4.19E-08	0.00E+00	Th-231	2.60E+06	2.60E+06
Ir-188	0.00E+00	0.00E+00	Th-232	8.07E-02	8.86E-02

Bq/bundle					
Nuclide	6 Year Decayed	10 Year Decayed	Nuclide	6 Year Decayed	10 Year Decayed
Ir-189	0.00E+00	0.00E+00	Th-234	2.47E+08	2.47E+08
Ir-190	0.00E+00	0.00E+00	Ti-44	7.17E-08	6.85E-08
Ir-191m	0.00E+00	0.00E+00	Tl-202	4.19E-02	4.19E-02
Ir-192	7.68E+01	8.46E-05	Tl-204	9.66E+08	4.64E+08
Ir-193m	0.00E+00	0.00E+00	Tl-206	3.37E+02	3.37E+02
Ir-194	8.68E+04	5.46E+04	Tl-207	1.39E+02	2.47E+02
K-40	5.79E+02	5.79E+02	Tl-208	1.44E+05	1.93E+05
K-42	2.59E+01	2.38E+01	Tl-209	3.54E-02	5.06E-02
Kr-81	2.34E+04	2.34E+04	Tl-210	4.42E-03	1.04E-02
Kr-83m	5.10E-02	4.02E-07	Tm-167	0.00E+00	0.00E+00
Kr-85	1.42E+12	1.09E+12	Tm-168	1.76E-01	3.31E-06
La-137	1.73E+04	1.73E+04	Tm-170	1.09E+06	4.14E+02
La-138	1.93E-01	1.93E-01	Tm-171	6.00E+08	1.42E+08
La-140	0.00E+00	0.00E+00	U-230	0.00E+00	0.00E+00
Lu-172	1.23E-01	2.79E-02	U-232	5.38E+05	5.96E+05
Lu-172m	1.23E-01	2.79E-02	U-233	1.63E+03	2.01E+03
Lu-173	4.22E+03	5.57E+02	U-234	1.90E+08	1.91E+08
Lu-174	3.06E+05	1.33E+05	U-235	2.60E+06	2.60E+06
Lu-174m	2.80E+01	2.24E-02	U-236	3.96E+07	3.97E+07
Lu-176	4.06E-02	4.06E-02	U-237	4.24E+08	3.49E+08
Lu-177	3.83E+02	6.95E-01	U-238	2.47E+08	2.47E+08
Lu-177m	1.72E+03	3.11E+00	U-240	1.80E+01	1.80E+01
Mn-53	1.30E+01	1.30E+01	V-48	0.00E+00	0.00E+00
Mn-54	9.63E+07	3.75E+06	V-49	6.36E+04	2.96E+03
Mo-93	4.15E+05	4.15E+05	V-50	2.06E-06	2.06E-06
Mo-100	9.99E-05	9.99E-05	W-178	0.00E+00	0.00E+00
Na-22	3.25E+03	1.12E+03	W-180	1.60E-08	1.60E-08
Nb-91	6.48E+03	6.45E+03	W-181	1.22E+04	2.87E+00
Nb-91m	1.27E-05	7.55E-13	W-183m	0.00E+00	0.00E+00
Nb-92	3.42E+00	3.42E+00	W-185	1.02E+02	1.42E-04
Nb-92m	0.00E+00	0.00E+00	W-186	3.84E-08	3.84E-08
Nb-93m	1.84E+08	2.15E+08	W-188	3.84E-01	1.91E-07
Nb-94	1.17E+07	1.17E+07	Xe-127	7.70E-13	0.00E+00
Nb-95	6.53E+04	8.83E-03	Xe-129m	0.00E+00	0.00E+00
Nb-95m	3.39E+02	4.58E-05	Xe-131m	0.00E+00	0.00E+00
Nd-144	2.99E-01	2.99E-01	Xe-133	0.00E+00	0.00E+00
Nd-147	0.00E+00	0.00E+00	Y-88	7.85E+01	5.89E-03

Bq/bundle					
Nuclide	6 Year Decayed	10 Year Decayed	Nuclide	6 Year Decayed	10 Year Decayed
Nd-150	1.19E-05	1.19E-05	Y-89m	2.42E-03	4.78E-12
Ni-59	2.56E+07	2.56E+07	Y-90	1.28E+13	1.17E+13
Ni-63	3.32E+09	3.23E+09	Y-91	2.05E+03	6.24E-05
Np-235	2.19E+03	1.70E+02	Yb-169	1.68E-15	0.00E+00
Np-236	4.54E+01	4.54E+01	Zn-65	1.20E+08	1.88E+06
Np-237	2.16E+07	2.20E+07	Zr-88	1.99E-05	1.06E-10
Np-238	1.38E+06	1.36E+06	Zr-93	3.86E+08	3.86E+08
Np-239	1.04E+09	1.04E+09	Zr-95	2.96E+04	4.00E-03
Np-240	2.16E-02	2.16E-02	Zr-96	3.70E-04	3.70E-04
Np-240m	1.80E+01	1.80E+01	-	-	-

Appendix B HAZARD PRE-SCREENING

Category	Hazard	Screening Status	Rationale	Reference
H-EXT	**External Hazards – Human Induced**			
Mobile Sources				
H-EXT-1	**Aircraft Impact**			
H-EXT-1.1	Aircraft Strike	IN	This hazard is expected to cause damage to the PWMF and may lead to a radiological release. This hazard is further assessed in Sections 5.4.2.12, 5.4.3.12 and 5.4.4.10.	N-GUID-03611-10001 Vol.8 [15]
H-EXT-2 Rail Transportation Hazards				
H-EXT-2.1	Train Crash	OUT	The CN Rail main line runs north of the PNGS, at approximately 3 km to the PWMF and the CP Rail mainline is located approximately 6 km north of the site [28]. Based on [15], the screening distance for train derailment is estimated to be 80 m (3-rail-car length) from the crash. Therefore, this hazard can be screened out based on the distance from the PWMF.	N-GUID-03611-10001 Vol.8 [15] NK30-REP-03611-00008 [28]
H-EXT-2.2	Cold Toxic Gas Release	OUT	The CN Rail mainline runs North of the PNGS, at approximately 3 km to the PWMF and the CP Rail mainline is located approximately 6 km north of the site [28]. Table 3-1 of [15] shows the SDV for Cold Toxic Gases. a) SDV for Ammonia, Hydrochloric Acid and Hydrogen Fluoride releases is 0.9 km and 1.4 km, respectively. This means	N-GUID-03611-10001 Vol.8 [15] NK30-REP-03611-00008 [28]

Category	Hazard	Screening Status	Rationale	Reference
			that these toxic materials can be screened out based on distance. b) SDV for Chlorine, Sulphuric Acid and Sulphur Dioxide is 4.4 km. This hazard can be screened out based on frequency (8.81E-07), refer to Table 3-9 of [28].	
H-EXT-2.3	Hot Toxic Gas Release	OUT	The CN Rail mainline runs North of the PNGS, at approximately 3 km to the PWMF and the CP Rail mainline is located approximately 6 km north of the site [28]. Table 3-2 of [15] shows that the maximum SDV is 2.3 km (sulphur dioxide) for hot toxic gases. Therefore, this hazard can be screened out based on the distance from the PWMF.	N-GUID-03611-10001 Vol.8 [15] NK30-REP-03611-00008 [28]
H-EXT-2.4	BLEVE – Missile Damage	OUT	The CN Rail mainline runs North of the PNGS, at approximately 3 km to the PWMF and the CP Rail mainline is located approximately 6 km north of the site [28]. Based on [15], the BLEVE SDV is estimated to be 1600 m. Therefore, the BLEVE hazard from rail derailment can be screened out based on the distance from the PWMF.	N-GUID-03611-10001 Vol.8 [15] NK30-REP-03611-00008 [28]
H-EXT-2.5	BLEVE – Blast Wave	OUT	The blast waves associated with a BLEVE are localized and not as strong as a Vapour Cloud Explosion (VCE). Since this hazard is bounded by the VCE hazard, it is not included in the screening analysis.	N-GUID-03611-10001 Vol.8 [15]
H-EXT-2.6	Vapour Cloud	OUT	The CN Rail mainline runs North of the PNGS,	N-GUID-03611-10001

Category	Hazard	Screening Status	Rationale	Reference
	Explosion (VCE)		at approximately 3 km to the PWMF and the CP Rail mainline is located approximately 6 km north of the site [28]. Based on [15], the Vapour Cloud Explosion SDV is estimated to be 460 m. Therefore, this hazard can be screened out based on the distance from the PWMF.	Vol.8 [15] NK30-REP-03611-00008 [28]
H-EXT-2.7	Explosions	OUT	The CN Rail mainline runs North of the PNGS, at approximately 3 km to the PWMF and the CP Rail mainline is located approximately 6 km north of the site [28]. Based on [15], the SDV is estimated to be 700 m. Therefore, this hazard can be screened out based on the distance from the PWMF.	N-GUID-03611-10001 Vol.8 [15] NK30-REP-03611-00008 [28]
H-EXT-3 Road Transportation Hazards				
H-EXT-3.1	Cold Toxic Gas Release, such as: Ammonia, Hydrochloric Acid and Hydrogen Fluoride; Hot Toxic Gases, BLEVEs, VCEs, and Explosions	OUT	As major roads/highways are slightly further away from the plant than the railway, these offsite road transportation accidents can be screened out based on distance.	N-GUID-03611-10001 Vol.8 [15]
H-EXT-3.2	Cold Toxic Gas Release e.g. Chlorine; Sulphuric Acid, Sulphur Dioxide	OUT	As per N-GUID-03611-10001, only 10% of these chemicals are transported on Highway 401 compared to the CN rail line traffic. This hazard can be screened out based on frequency (8.81E-08), refer to Table 3-11 of [28].	N-GUID-03611-10001 Vol.8 [15] NK30-REP-03611-00008 [28]

Category	Hazard	Screening Status	Rationale	Reference
H-EXT-4 Ship Accidents				
H-EXT-4.1	Small Vessels	OUT	Boats/small vessels are not permitted to dock on the shore near the PWMF. Small vessels will not have an impact on the PWMF site; therefore this hazard can be screened out.	N-GUID-03611-10001 Vol.8 [15]
H-EXT-4.2	Large Vessels	OUT	As per [15], the normal shipping lanes in Lake Ontario are 10 kilometres away from the shoreline in the vicinity of the plant. In addition, there are no commercial wharfs around the Pickering area, see [28]. Therefore, this hazard can be screened out based on the distance from the PWMF.	N-GUID-03611-10001 Vol.8 [15] NK30-REP-03611-00008 [28]
Stationary Sources				
H-EXT-5	Nearby Nuclear Event	OUT	An accident at the Pickering A, Pickering B or DNGS, resulting in significant releases would progress slowly enough to ensure notification to PWMF personnel such that the required actions could be taken. Any anticipated dose from the PWMF as a result of a significant event at either Pickering A or Pickering B, would be bounded by the dose received from the station itself. Therefore, this hazard can be screened out.	N-GUID-03611-10001 Vol.8 [15]
H-EXT-6 Toxic Gas Release				
H-EXT-6.1	Toxic Gas Release – Chlorine originated from Ajax Water Treatment Plant	IN	The Ajax Water Treatment Plant is situated near the Ajax Waterfront Park, and uses chlorine cylinders for water treatment. As per Table 3-1 of [15], the SDV for Chlorine is 4.4 km.	N-GUID-03611-10001 Vol.8 [15]

Category	Hazard	Screening Status	Rationale	Reference
			The Ajax Water Treatment facility is located at approximately 4.1 km from Phase II site. Since the SDV for chlorine is 4.4 km, this hazard cannot be screened out based on distance. This hazard is further assessed in Section 5.4.2.13	
H-EXT-6.2	Toxic Gas Release - Chlorine originated from the Duffin Creek Water Pollution Control Plant	OUT	The Duffin Creek Water Pollution Control Plant, using chlorine is located in Pickering at 1.2 km from the PWMF Phase II site. Due to its proximity, it may be able to release sufficient chlorine to impair the DSC transporter operator. Since the SDV for chlorine is 4.4 km, this hazard cannot be screened out based on distance. However, based on the annual frequency of chlorine leak from a fixed storage tank, 2.86E-07, refer to Table 3-12 of [28], this hazard can be screened out.	NK30-REP-03611-00008 [28] N-GUID-03611-10001 Vol.8 [15]
H-EXT-7	BLEVE	OUT	External fixed sources of BLEVEs have been identified within a radius of 5 km of PNGS [28] and it was concluded that none of the sites were within the SDV, which is 1600 m for BLEVE, refer to [15]. Therefore, this hazard can be screened out based on distance.	NK30-REP-03611-00008 [28] N-GUID-03611-10001 Vol.8 [15]
Other Sources				
H-EXT-8	Missiles from Military Activity	OUT	As per [15], this is considered a malevolent act. Therefore, it is out of scope.	N-GUID-03611-10001 Vol.8 [15]
H-EXT-9	Orbital Debris Crashes	OUT	According to [15], there is no SDV for this hazard type. Orbital debris can cause serious damage to the DSCs. However, based on the annual frequencies of	N-GUID-03611-10001 Vol.8 [15] P-REP-03611-00009

Category	Hazard	Screening Status	Rationale	Reference
			this hazard of: • 1.6E-08 occurrence/ year for the UFDS facilities, refer to Section 3.9 of [37] (including the total PWMF Phase I and Phase II storage area, with planned SB4). Taking into account that the Phase II storage area is smaller, the frequency of occurrence is lower; • The annual frequency of orbital debris impacting the DSC transporter was conservatively determined to be 7.2×10^{-7} events/year, refer to Section 5.5 of [24], which is already below the cutoff frequency of 10^{-6}. This value will considerably decrease when the likelihood of having a DSC in transit is taken into account. This hazard can be screened out.	[37] 92896-REP-00120-00005 [24]
N-EXT External Hazards – Natural				
N-EXT-1	Earthquake	IN	The ground motion associated with this event may exceed the design capacity of the PWMF SSCs. This hazard has the potential to lead to a radiological release; therefore, it cannot be screened out. This hazard is further assessed in Sections 5.4.2.6, 5.4.3.7 and 5.4.4.8	N-GUID-03611-10001 Vol.8 [15]
N-EXT-2	**Soil Failures**			
N-EXT-2.1	Slope Instability	IN	1) During DSC On-site Transfer As per [15] and [28], the PNGS site complies with the specific clauses of the Canadian	N-GUID-03611-10001 Vol.8 [15]

Category	Hazard	Screening Status	Rationale	Reference
			Foundation Engineering Manual and the National Building Code of Canada (NBCC). However, it has been identified that the DSC transport route between the PNGS B Irradiated Fuel Bay (IFB) or PNGS A Auxiliary Irradiated Fuel Bay (AIFB) and the DSC Processing Building at the PWMF – Phase I, has some anomalous portions, [92896-REP-00120-00005 R000]. Detailed geotechnical assessment has been recommended. In addition, reference [38] identified a lower priority anomaly along the transfer route from PWMF Phase I to Phase II, near the north-west corner of SB3. This hazard cannot be screened out for the DSC on-site transfer from Phase I to Phase II. This hazard requires further assessment and it is assessed in Section 5.4.2.14	NK30-REP-03611-00008 [28] 92896-REP-00120-00005 [24] P-CORR-76310-0395173 [38]
N-EXT-2.2	Subsidence	OUT	As per [15] and [28], the PNGS site is not situated in a geographical area where subsidence can occur. Therefore, this hazard can be screened out.	N-GUID-03611-10001 Vol.8 [15] NK30-REP-03611-00008 [28]
N-EXT-2.3	Swelling Clay	OUT	Based on [15] the foundations of PNGS are not on clay layers. Therefore, this hazard can be screened out.	N-GUID-03611-10001 Vol.8 [15]
N-EXT-2.4	Soil Frost	OUT	Based on Reference [15] this hazard may affect	N-GUID-03611-10001

Category	Hazard	Screening Status	Rationale	Reference
			the integrity of buried piping. This hazard is not applicable to the present PWMF safety assessment.	Vol.8 [15]
N-EXT-3 Flooding				
N-EXT-3.1	Flooding Due to Runoff	IN	A probable maximum precipitation (PMP) event can impact the PWMF SSCs ; this hazard will require, further assessment and it is assessed in Sections 5.4.2.9, 5.4.3.10 and 5.4.4.7.	N-GUID-03611-10001 Vol.8 [15]
N-EXT-3.2	Flooding Due to River	OUT	Main river courses are located at a distance greater than 2 km from the western (Rouge River and the Petticoat Creek) and eastern (Duffin's Creek) boundary of the PNGS site [28]. Based on distance, the potential for these rivers to represent a potential flood hazard to the PWMF is screened out. Krosno Creek is located immediately to the west of the PNGS and is prone to flooding. Based on Reference [28], an assessment has been conducted in 2011 as part of the Fukushima follow-up and it was determined that Krosno Creek would maintain at minimum approximately 2.7 m of freeboard from a potential spill during flooding due to a PMP event. Based on this, the potential for flooding from this river can be screened out.	N-GUID-03611-10001 Vol.8 [15] NK30-REP-03611-00008 [28]
N-EXT-3.3	Flooding Due to	OUT	The Processing Building is at elevation 77.4m	92896-DRAW-29651-

Category	Hazard	Screening Status	Rationale	Reference
	Waves		(254’) [39] and at a minimum distance of 75 m (the RCS area width) north of the lakeshore. The SB3 elevation is 83.53 m [40]. For an assumed lake level of 74.5 m (mean winter condition), wave uprushes have been estimated at 0.2 m and 1.8m [28]. The maximum wave run-up heights (76.3 m) are below the PWMF site. For an assumed (100-year) lake level of 75.6 m (Review Level Conditions – Lake Level) and with wave uprushes of 2.20 m, refer to Section 4.1 and Table 4-1 of [28], the maximum wave run-up heights are 77.8 m. Taken into account the elevation of the PWMF Phase I and Phase II sites and the distance of the Processing Building with respect to the lake, this hazard is screened out.	10075 [40]
N-EXT-3.4	Flooding Due to Seiche	OUT	Section 4.4.4 of Reference [28] notes that the site requires protection for water surge of up to 0.75 m, as the highest modeled water level at Darlington resulting from surge or seiche is about 0.75 m. The 100-year maximum lake level is 75.6 m, so the possible maximum level is 76.35 m. Phase II SB3 is situated at 83.53 m elevation; this hazard is screened out.	NK30-REP-03611-00008 [28] 92896-DRAW-29651-10075 [40]
N-EXT-3.5	Flooding Due to	OUT	Based on Section 4.4.5 of Reference [28], a	N-GUID-03611-10001

Category	Hazard	Screening Status	Rationale	Reference
	Tsunami		tsunami in Lake Ontario is an improbable event, with no associated flood hazard potential. Furthermore, the Great Lakes are in a geologically stable, mid-continental region, where the probability of occurrence of earthquakes large enough to generate tsunamis is negligible. Therefore, this hazard can be screened out.	Vol.8 [15] NK30-REP-03611-00008 [28]
N-EXT-3.6	Flooding Due to Sudden Releases of Water from Natural or Artificial Storage	OUT	As per Section 4.4.6 of [28], no large lakes and no man-made water retaining structures creating reservoirs are located within the drainage areas in the vicinity of the PNGS that could influence flooding. For this reason, this hazard can be screened out.	N-GUID-03611-10001 Vol.8 [15] NK30-REP-03611-00008 [28]
N-EXT-3.7	Flooding Due to Ice-jamming	OUT	Rapid melting of snow and large blocks of ice accumulated on the buildings' rooftop and at site as the temperature rises above the freezing point (late winter/early spring) can cause flooding. Section 7 of [18] states that the *DSC shall be designed that water from melting snow cannot enter the DSC.* Therefore this hazard can be screened out.	N-GUID-03611-10001 Vol.8 [15] NK30-REP-03611-00008 [28] 00104-DR-79171-10000 [18]
N-EXT-3.8	Flooding Due to Other Causes	OUT	Other causes of flooding may include underwater landslides and lake ice. Lake Ontario shorelines as a whole are not susceptible to shore slope failure or landslide [28]. Lake ice can be also screened out as a flood hazard as ice structures are not expected	N-GUID-03611-10001 Vol.8 [15] NK30-REP-03611-00008 [28]

Category	Hazard	Screening Status	Rationale	Reference
			to create or worsen any coastal flood hazard at Pickering [28].	92896-REP-00120-00005 [24]
N-EXT-4 Meteorological – Extremes				
N-EXT-4.1	Temperature (extreme high/ extreme low)	OUT	DSC on-site transfer: Procedures are in place to prohibit DSC transfer under poor or slippery road conditions. Even if the on-site transfer of a DSC takes longer than expected as result of adverse road conditions, the radiological consequences would be bounded by a transporter failure incident, refer to Section 5.4.2.1. Furthermore, as per Section 4.1, Transportation, of the DSC design requirements [18]: "*the materials and effectiveness of the components of the DSC shall not be degraded within the temperature range -40C to +70C*." This hazard can be screened out.	N-GUID-03611-10001 Vol.8 [15] 00104-DR-79171-10000 [18]
N-EXT-4.2	Snowpack	OUT	Waste transfer activities should not be performed during snow-covered conditions, and are bounded by a transporter failure incident. Section 7 of the DSC design requirements [18] states that the "*DSC shall not be degraded by exposure to snow* and the *DSC shall be designed that water from melting snow cannot enter the DSC".* In addition, the impact of the snowpack load on the DSC has to be taken into consideration.	N-GUID-03611-10001 Vol.8 [15] 00104-DR-79171-10000 [18]

Category	Hazard	Screening Status	Rationale	Reference
			As per Table 2 of [18], the DSC shall withstand *"compressive load for 24 hours of either five times the actual DSC package mass or 13 kPa multiplied by the vertically projected area of the DSC package."* Based on the above requirements, the snowpack hazard can be screened out.	
N-EXT-4.3	Freezing Rain	OUT	The impact of freezing rain is bounded by the impact of external flood, ice-storms and snowpack. Procedures are in place to prohibit DSC transfer under poor or slippery road conditions. Even if the on-site transfer of a DSC takes longer than expected as result of adverse road conditions, the radiological consequences would be bounded by a transporter failure incident. This hazard is screened out.	N-GUID-03611-10001 Vol.8 [15] 92896-REP-00120-00005 [24]
N-EXT-4.4	Extreme Water Temperature	OUT	Operation of the PWMF does not depend on the use of lake water.	N-GUID-03611-10001 Vol.8 [15]
N-EXT-4.5	Avalanches	OUT	The PNGS is not situated in a mountainous region with large slopes which would lead for a large avalanche.	N-GUID-03611-10001 Vol.8 [15]
N-EXT-4.6	Lightning	OUT	Section 4.2 of 00104-DR-79171-10000 [18] states that "*the DSC shall be designed to maintain its structural integrity, appropriate shielding and containment function for severe atmospheric conditions during on-site transfer*	N-GUID-03611-10001 Vol.8 [15] 00104-DR-79171-10000 [18]

Category	Hazard	Screening Status	Rationale	Reference
			and storage." This hazard is bounded by a thunderstorm hazard, refer to Sections 5.4.2.8, 5.4.3.9, 5.4.4.6 and is screened out.	
N-EXT-4.7	Hurricanes	OUT	Tornadoes are more frequent in the region of concern and the impact of a tornado is considered bounding for high-winds category of hazard. Therefore, the wind speeds from tornadoes will be considered a bounding hazard.	
N-EXT-4.8	Tornadoes	IN	This hazard is expected to cause significant damage to the PWMF SSCs; therefore it will require further assessment and it is assessed in Sections 5.4.2.7, 5.4.3.8, and 5.4.4.5	N-GUID-03611-10001 Vol.8 [15]
N-EXT-4.9	Sand Storms	OUT	Sandstorms are typically associated with deserts. In the vicinity of the PWMF there are no large sand-bodies, therefore sandstorms are not a credible potential external hazard for Ontario.	N-GUID-03611-10001 Vol.8 [15]
N-EXT-4.10	Ice Storms	OUT	Waste transfer activities should not be performed during slippery conditions, and are bounded by transporter failure incident and adverse road conditions, refer to Sections 5.4.2.1 and 5.4.2.5, respectively.	92896-REP-00120-00005 [24] 00104-DR-79171-10000 [18]

Category	Hazard	Screening Status	Rationale	Reference
			During storage in SB3: Based on the design requirements [18], the DSC, while in storage, will withstand storage building structural failure or collapse without loss of shielding or containment. This hazard does not require further assessment.	
N-EXT-4.11	Frazil Ice	OUT	Operation of the PWMF does not depend on the use of the lake water.	N-GUID-03611-10001 Vol.8 [15]
N-EXT-4.12	Low Lake Level/Drought	OUT	Operation of the PWMF does not depend on the use of the lake water.	N-GUID-03611-10001 Vol.8 [15]
N-EXT-4.12	Meteorites	OUT	Similar to the orbital debris hazard, this hazard cannot be screened out based on qualitative screening. However, the annual frequencies of this hazard are[6]: • 5.91E-08 occurrence/ year for the UFDS facilities (including SB4), refer to Table 4-1 of [37]. • The annual frequency of meteorites impacting the DSC transporter was conservatively determined to be 1.96x10-7 events/year, refer to Section 5.4 of [24], which is already below the cutoff frequency of 10-6. This value will considerably decrease when the likelihood of having a DSC in transit is taken into account. These values are lower than the cut-off	N-GUID-03611-10001 Vol.8 [15] P-REP-03611-00009 [37] 92896-REP-00120-00005 [24]

Category	Hazard	Screening Status	Rationale	Reference
			frequency of 10^{-6}, therefore this hazard is screened out.	
N-EXT-4.13	Geomagnetic storm	OUT	Geomagnetic storm events will impact the power distribution system equipment and may cause loss of off-site power. This hazard does not impact the PWMF site; therefore, it is screened out.	N-GUID-03611-10001 Vol.8 [15] NK30-REP-03611-00008 [28]
N-EXT-5 Other Hazards				
N-EXT-5.1	Forest Fire	OUT	There is no heavily forested area around 3 km of the site [24]. SDV for this hazard is 1 km [15]. Therefore, this hazard is screened out.	92896-REP-00120-00005 [24] N-GUID-03611-10001 Vol.8 [15]
N-EXT-5.2	Corrosion from Salt Water	OUT	This hazard is not applicable in the Great Lakes area; therefore, this hazard is screened out.	N-GUID-03611-10001 Vol.8 [15]
N-EXT-5.3	Animals	OUT	As per reference [15], it would require large numbers of animals to challenge the operation of the station. However, large numbers of animals will be restricted from entering the PWMF as the facility is within the protected area fence. Therefore, this hazard does not have any impact on the PWMF site or the DSC on-site transfer.	N-GUID-03611-10001 Vol.8 [15]
H-INT	**Internal Hazards**			
H-INT-1	Turbine Generated Missiles	IN	**During DSC on-site transfer** Pickering B Unit 8 Turbine is in close proximity to the DSC transfer routes. A missile may have	N-GUID-03611-10001 Vol.9 [14]

Category	Hazard	Screening Status	Rationale	Reference
			an impact on the transfer and processing in the Phase I Processing Building. This hazard requires further assessment and it is assessed in Section 5.4.2.11. **During DSC processing** Phase I of the PWMF is located southeast of PNGS Unit 8 with SB2 is situated the closest, at approximately 30 m, to Unit 8. A missile may have an impact on the Phase I structures, therefore this hazard requires further assessment and it is assessed in Section 5.4.3.11. **During DSC storage in SB3** The Phase II SB3 is located approximately 500 m northeast of Pickering B Unit 8, the closest unit to the PWMF site. The building is separated by distance from the Unit 8 turbine, and it is also shielded by various buildings located between the two facilities. The frequency of turbine missiles impacting SSCs has been determined to be $6x10^{-6}$ events/year [3]. Based on the low frequency of a turbine missile impacting an SSC and taking into account the location of the SB3 with reference to the Unit 8 turbine, this hazard is not further assessed.	
H-INT-2	Other Mechanically Generated Missiles	OUT	The effect of missiles from other components, such as pumps and valves is assumed bounded by the turbine missiles hazard. This hazard can be screened out.	N-GUID-03611-10001 Vol.9 [14]

Category	Hazard	Screening Status	Rationale	Reference
H-INT-3	Acetylene Decomposition Explosion Missile	OUT	Based on Section 3.1.2 of [20], the explosion frequency caused by acetylene cylinder explosion, adversely affecting the transported DSC, is 2.7E-08 events/year. Based on frequency, this event is screened out.	N-GUID-03611-10001 Vol.9 [14] 92896-REP-00120-00003 [20]
H-INT-4	Missiles Generated by a Hydrogen Explosion at the Tritium Removal Facility	OUT	This hazard is associated with the tritium removal facility at DNGS and is not applicable for the Pickering site.	N-GUID-03611-10001 Vol.9 [14]
H-INT-5	Control Rod Ejection Missiles	OUT	This hazard is not applicable due to the design of a CANDU reactor.	N-GUID-03611-10001 Vol.9 [14]
H-INT-6	**Release of Toxic, Radioactive or Corrosive Gases and Liquids from On-Site Storage**			
H-INT-6.1	Acute Inhalation Toxicity	IN	Toxic materials are not considered to be stored along the transfer route. There are toxic materials stored in the Processing Building and in SB3, therefore this hazard requires further assessment. This hazard is discussed in Sections 5.4.3.13 and 5.4.4.9.	N-GUID-03611-10001 Vol.9 [14]
H-INT-6.2	Corrosion	OUT	Quantities for corrosive materials are not shown on the latest Hazardous Material Inventory sheets. Based on previous Hazardous Material Inventory sheets (with quantities included) and the nature of the corrosive materials stored in Room 110, cabinets 32 and 6666 in the	N-GUID-03611-10001 Vol.9 [14]

Category	Hazard	Screening Status	Rationale	Reference
			Processing Building, it was concluded that there are less than 50 gallons of corrosive materials stored in the Processing Building. Therefore this hazard can be screened out.	
H-INT-6.3	Oxidizing/Reactive Chemicals	OUT	It was not confirmed by OPG that there is oxygen gas stored in the PWMF Processing Building. Therefore this hazard is screened out.	N-GUID-03611-10001 Vol.9 [14]
H-INT-6.4	Asphyxiants	IN	There are asphyxiating gases (argon, helium and nitrogen) stored in the workshop and gas bottle storage room in the Processing Building. Therefore this hazard requires further assessment and it is assessed in Section 5.4.3.13.	N-GUID-03611-10001 Vol.9 [14]
H-INT-7	Release of Stored Energy	OUT	Catastrophic failure of pressure vessels are excluded from consideration. There are no other sources of significant stored energy, such as high pressure piping associated with the PWMF.	N-GUID-03611-10001 Vol.9 [14]
H-INT-8	**On-Site Transfer**			
H-INT-8.1	Vehicle Impacts - Onsite Vehicle Movements	IN	Accident of vehicles with the DSC transporter during on-site transfer of the DSC has the potential to lead to radiological release. Therefore, this hazard is screened in. Further assessment is provided in Sections 5.4.2.1, 5.4.2.2 and 5.4.2.3.	N-GUID-03611-10001 Vol.9 [14]

Category	Hazard	Screening Status	Rationale	Reference
H-INT-8.2	Vehicle Impacts Within the PWMF Buildings	IN	The movement (craning, lifting, re-arrangement) of the DSCs within the PWMF buildings has the potential to lead to radiological release. Therefore, this hazard is screened in. This hazard is assessed in Sections 5.4.3.1, 5.4.3.2, 5.4.3.3, 5.4.3.4, 5.4.3.5, 5.4.4.2, 5.4.4.3.	N-GUID-03611-10001 Vol.9 [14]
H-INT-8.3	Toxic and/or Dangerous Goods - Onsite Vehicle Movements	OUT	This hazard is bounded by vehicle accidents involving radiological waste.	
H-INT-8.4	BLEVE – Blast Wave	OUT	The frequency of missile sources originating from propane tank explosion (BLEVE) along the transporter on-site transfer route is 3.4E-09 events/yr, refer to Section 3.2 of [20]. This hazard is screened out.	N-GUID-03611-10001 Vol.9 [14] 92896-REP-00120-00003 [20]
H-INT-8.5	Vapour Cloud Explosion (VCE)	OUT	The frequency of missile sources originating from propane tank explosion (VCE) along the transporter on-site transfer route is 2.1E-08 events/yr, refer to Section 3.3 of [20]). This hazard is screened out.	N-GUID-03611-10001 Vol.9 [14] 92896-REP-00120-00003 [20]
H-INT-9	Collapsed Structures	OUT	This hazard is bounded by earthquakes.	
H-INT-10	Fire – Toxic Effects Only	OUT	The effects of this hazard are bounded by fire.	
H-INT-11	Dropped or impacting loads	IN	The dropping of DSCs during handling can lead to radioactive release. This hazard needs further	N-GUID-03611-10001 Vol.9 [14]

Category	Hazard	Screening Status	Rationale	Reference
			assessment and it is assessed in Sections 5.4.3.1 and 5.4.4.2.	
H-INT-12	Electromagnetic Interference (EMI) and Radio-Frequency Interference (RFI)	OUT	EMI and RFI can affect the proper operation of digital instrumentation, I&C systems or advanced analog systems [14]. DSCs will not be affected by either the EMI or RFI.	N-GUID-03611-10001 Vol.9 [14]
H-INT-13	Static Electricity	OUT	The discharge of static electricity may impact the performance of control systems and control centers [14]. DSCs will not be affected by static electricity.	N-GUID-03611-10001 Vol.9 [14]
H-INT-14	Criticality related events	OUT	Based on the criticality assessment documented in the 1998 issue of the PWMF Safety Assessment, Appendix G, the Pickering used fuel stored in DSCs cannot achieve criticality under normal conditions or credible abnormal scenarios.	N-GUID-03611-10001 Vol.9 [14]
H-INT-15	High Temperature Surfaces	OUT	This hazard is bounded by fire.	N-GUID-03611-10001 Vol.9 [14]
H-INT-16	Fire	IN	Fires may lead to damage of the PWMF SSCs, therefore this hazard will require further assessment and it is assessed in Sections 5.4.2.4, 5.4.3.6 and 5.4.4.4	N-GUID-03611-10001, Vol9

Appendix C AIRCRAFT CRASH FREQUENCY CALCULATIONS

This Appendix presents the PWMF aircraft crash frequency calculations. The calculation is based on Appendix B of Reference [41] and consists of calculating the effective area of the target and multiplying that by the aircraft crash rate.

The effective target area is calculated as:

Aeff = Af + As where

where:

Af = (WS + R) x H x cotΦ + (2 x L x W x WS)/R + L x W, and

As = (WS+R) x S

where:

- Af = effective fly-in area
- As = effective skid area
- WS = aircraft wingspan
- R = length of the diagonal of the facility
- H = facility height
- cotΦ = mean of the cotangent of the aircraft impact angle
- L = length of facility
- W = width of facility
- S = aircraft skid distance

Table C-1 shows the total crash rates calculated for the PNGS site for the five aircraft categories, taken from Table 3-2 of Reference [28]. Airports located in a radius of about 35 kilometres from the PNGS were considered in the airfield crash rate calculation.

The aircraft crash frequency for the PWMF was calculated by the summation of the crash frequencies in those areas where DSCs are stored or processed.

A qualitative aircraft impact assessment (AIA) was performed for the DSC against light general aviation aircraft crashes [42] and concluded that the Category 1 aircraft, which is a light aircraft, will not cause damage to a DSC except for slight concrete cracking or scabbing, therefore this aircraft type was not included in the DSC aircraft crash frequency calculations.

The aircraft crash frequency calculations were performed for Aircraft categories 2 to 5 for the areas occupied by the PWMF Phase I and Phase II structures.

In addition, the total aircraft crash frequency for the PWMF structures holding safety related waste containers, such as DSCs and Dry Storage Modules (DSM) [43] was determined by summation of the frequency of an aircraft crash impacting the DSC processing and storage buildings and Retube Component Storage (RCS) area where the DSMs are stored. For the RCS area aircraft crash frequency calculation all aircraft categories (Category 1 to 5) were considered.

The PWMF Phase I SB1, SB2 and Processing Building occupy a total area of approximately 312 ft x 342 ft [44]. The height of the Phase I facility is 45 ft [39]. The aircraft crash frequency calculated for the PWMF Phase I area is 2.42×10^{-7} events/year.

The RCS facility occupies a total fenced area of approximately 75 m x 85 m [3] and it is located south of the Phase I area. The aircraft crash frequency for the RCS area was calculated to be 2.54×10^{-7} event/year.

SB3 has a total area of 279.06 ft x 238 ft [45]. Storage Building 4 occupies a total area of 275.33 ft x 270.67 ft [46]. The total area of SB3 and SB4 was calculated using the following dimensions: total length of SB3+SB4 (275.33+279.06) ft and the greater width of the two buildings: 270.67 ft. The height of both SB3 and SB4 is 9.6 m (31.5 ft) [45]. The aircraft crash frequency calculated for the PWMF Phase II area is 2.92×10^{-7} events/year.

The summation of the above aircraft crash frequencies calculated for the PWMF site where safety-related containers are stored or processed is:

$$2.42 \times 10^{-7} + 2.54 \times 10^{-7} + 2.92 \times 10^{-7} = 7.88 \times 10^{-7} \text{events/year}$$

This value is below the cut-off frequency of 10^{-6} events/year and is therefore screened out.

Table C-1 PNGS Airfield Crash Rates

Aircraft Category	Total Crash Rate (km^{-2} yr^{-1})
Light Aircraft (Category 1)	5.1E-06
Helicopters (Category 2)	3.6E-07
Small Transport (Category 3)	9.3E-07
Large Transport (Category 4)	1.2E-06
Military Combat (Category 5)	6.6E-08
Total for Large Aircraft (Categories 4 and 5)	-
Total for all Categories	-

Taken from Table 3-2 of Reference [28]

Table C-2 PWMF Aircraft Crash Frequency Calculations

		Category 1	Category 2	Category 3	Category 4	Category 5	Total Crash Frequency/Facility
		Light Aircraft	Helicopters	Small Transport	Large Transport	Military Combat	
Wingspan	WS, ft	73	50	59	98	110	
Skid distance	S, ft	60	0	1440	1440	447	
Cot impact angle	Cot q	8.2	0.58	10.2	10.2	10.4	
Crash rate	km^{-2} yr^{-1}	5.10E-06	3.60E-07	9.30E-07	1.20E-06	6.60E-08	
DSC On-Site Transfer with Liftking Transporter							
Transporter Length	L, ft	N/A	27.83	27.83	27.83	27.83	
Transporter Width	W, ft	N/A	10.88	10.88	10.88	10.88	
Diagonal of Transporter	R, ft	N/A	29.88	29.88	29.88	29.88	
Transporter Height	H, ft	N/A	15.52	15.52	15.52	15.52	
Effective fly area	Af. ft^2	N/A	2,034.68	15,568.33	22,532.27	25,109.22	
Effective skid area	As, ft^2	N/A	0.00	127,990.26	184,150.26	62,527.31	
Total Area	Aeff, ft^2	N/A	2,034.68	143,558.60	206,682.53	87,636.53	
	Aeff, km^2	N/A	0.00019	0.013	0.019	0.008	
Probability of a loaded transporter on-site	yr^{-1}	N/A	0.011	0.011	0.011	0.011	
Crash Frequency	yr^{-1}	N/A	7.77E-13	1.42E-10	2.63E-10	6.13E-12	**4.12E-10**
Phase I (Processing Building, SB1, SB2)							
Facility Length	L, ft	N/A	342.00	342.00	342.00	342.00	
Facility Width	W, ft	N/A	312.00	312.00	312.00	312.00	
Diagonal of Facility	R, ft	N/A	462.93	462.93	462.93	462.93	

		Category 1	Category 2	Category 3	Category 4	Category 5	Total Crash Frequency/Facility
		Light Aircraft	**Helicopters**	**Small Transport**	**Large Transport**	**Military Combat**	
Facility Height	H, ft	N/A	45.00	45.00	45.00	45.00	
Effective fly area	Af. ft^2	N/A	143,141.08	373,470.17	409,349.78	425,546.07	
Effective skid area	As, ft^2	N/A	0.00	751,585.13	807,745.13	256,101.55	
Total Area	Aeff, ft^2	N/A	143,141.08	1,125,055.30	1,217,094.91	681,647.62	
	Aeff, km^2	N/A	0.013	0.105	0.113	0.063	
Crash Frequency	yr^{-1}	N/A	4.79E-09	9.72E-08	1.36E-07	4.18E-09	**2.42E-07**
DSM/ RCS Area							
Facility Length	L, ft	278.8	278.8	278.8	278.8	278.8	
Facility Width	W, ft	246.00	246.00	246.00	246.00	246.00	
Diagonal of Facility	R, ft	371.81	371.81	371.81	371.81	371.81	
Facility Height	H, ft	16.07	16.07	16.07	16.07	16.07	
Effective fly area	Af. ft^2	154,130.86	90,962.37	160,967.49	181,748.03	189,690.59	
Effective skid area	As, ft^2	26,688.82	0.00	620,371.75	676,531.75	215,370.73	
Total Area	Aeff, ft^2	180,819.68	90,962.37	781,339.25	858,279.78	405,061.32	
	Aeff, km^2	0.017	0.008	0.073	0.080	0.038	
Crash Frequency	yr^{-1}	8.57E-08	3.04E-09	6.75E-08	9.57E-08	2.48E-09	**2.54E-07**
Phase II - DSC Storage Buildings SB3 and SB4							
Facility Length	L, ft	N/A	553.75	553.75	553.75	553.75	
Facility Width	W, ft	N/A	270.68	270.68	270.68	270.68	
Diagonal of Facility	R, ft	N/A	616.37	616.37	616.37	616.37	
Facility Height	H, ft	N/A	31.50	31.50	31.50	31.50	

		Category 1	Category 2	Category 3	Category 4	Category 5	Total Crash Frequency/Facility
		Light Aircraft	**Helicopters**	**Small Transport**	**Large Transport**	**Military Combat**	
Effective fly area	Af. ft^2	N/A	186,379.17	395,561.65	427,059.38	441,326.75	
Effective skid area	As, ft^2	N/A	0.00	972,528.32	1,028,688.32	324,686.00	
Total Area	Aeff, ft^2	N/A	186,379.17	1,368,089.97	1,455,747.70	766,012.75	
	Aeff, km^2	N/A	0.017	0.127	0.135	0.071	
Crash Frequency	yr^{-1}	N/A	6.23E-09	1.18E-07	1.62E-07	4.70E-09	**2.91E-07**
Total Crash Frequency for Phase I, RCS/DSM Area and Phase II:							**7.88E-07**

Notes:

i Light Aircraft dimensions were taken from Tables B-16/B-17 and B-18 of Reference [41], corresponding to General Aviation, TurboProp.

ii Small Transport dimensions were taken from Tables B-16/B-17 and B-18 of Reference [41], corresponding to Commercial Aviation, Air Taxi.

iii Large Transport dimensions were taken from Tables B-16/B-17 and B-18 of Reference [41], corresponding to Commercial Aviation, Air Carrier.

iv Military Combat dimensions were taken from Tables B-16/B-17 and B-18 of Reference [41], corresponding to Military Aviation, Small Aircraft Low Performance.

Appendix D ADDAM COMPUTER CODE

Computer Program Name	ADDAM [47]
Code Version	1.4.2
Operating System	Windows 7

Code description:

ADDAM is a safety analysis computer program developed by the Atomic Energy of Canada Limited (AECL) for use by the CANDU Owners Group (COG) community. ADDAM calculates doses to the public due to a postulated accident release of radioactive material to the atmosphere from a nuclear facility. Radionuclides being released can be in the form of gases, vapours or small particles. The radionuclides will disperse as a result of the effects of atmospheric turbulence. The dispersion of the release is affected by the characteristic of the release, the prevailing meteorological conditions, the surrounding terrain and the nearby buildings. The concentrations in the cloud and on the ground take into account factors such as the nature of the release (timing, composition and quantity), decay, build-up, and deposition. Doses are calculated for various organs, age groups, and receptor locations, and categorized by release pathways (stack, inlet, leakage, or hole) and exposure pathways (inhalation, cloudshine, groundshine). The calculations of atmospheric dispersion and doses are based on the CSA N288.2-M91 standard [48]. A recent code assessment documented in Reference [49] has confirmed that ADDAM is also in compliance with the CSA N288.2-14.

Use of code:

For the current analysis, the ADDAM code was used to predict dose to members of the public following postulated malfunciton / accident scenarios. Consistent with the CSA N288.2-14 [6], ADDAM has a limitation on the treatment of releases from fire scanario; however, the current safety assessment, there is no releases associated with the fire scenario.

Validation and code applicability:

The use of code for the current analysis is within the current ADDAM code range of applicability. The methodologies implemented in the ADDAM code has undergone a series of validation exercises. The phenomena that govern atmospheric dispersion and dose estimation in the context of safety analysis were identified and documented in the validation matrix for dispersion [50]. Phenomena that were validated were summarized in the ADDAM validation manual [51]:

- Plume rise;
- Downwash;
- Modification of effective height release due to building entrainment;
- Plume broadening due to building entrainment;
- Fumigation;
- Reflection at an elevated inversion;

- Plume transport;
- Plume diffusion;
- Wet deposition;
- Dry deposition;
- Plume depletion;
- Exposure to cloudshine;
- Exposure to groundshine; and
- Internal exposure due to inhalation.

The validation exercises conform with the requirements given in the CSA N286.7 standard. Note that since the ADDAM validation exercises were phenomena-based and the current version (1.4.2) still has the same underlying dispersion methodology, all validation results are still valid for the current version being used for the PWMF safety assessment.

Although there are still uncertainties associated with the ADDAM code in modeling some phenomena such as wet deposition, dry deposition, and plume depletion, the code has been developed with many conservative assumptions to ensure that the calculated doses are not underestimated.

Sofware Quality Assurance Documents:

Problem definition	COG document SQAD-15-5074, ADDAM Version 1.4.2 Problem Definition
Development plan	Section 4 of COG document SQAD-10-5087, ADDAM version 1.4.2 Model Development and Verification.
Theory manual	COG document SQAD-07-5008, ADDAM version 1.4 Theory Manual and Section 6 of COG document SQAD-10-5087, ADDAM version 1.4.2 Model Development and Verification.
Requirements specification	Section 5 of COG document SQAD-10-5087, ADDAM version 1.4.2 Model Development and Verification.
Design description	Section 7 of COG document SQAD-10-5087, ADDAM version 1.4.2 Model Development and Verification.
Verification report	Section 9 of COG document SQAD-10-5087, ADDAM version 1.4.2 Model Development and Verification.
Programmer's manual	Section 12 of COG document SQAD-10-5087, ADDAM version 1.4.2 Model Development and Verification.
Validation report	AECL RC-2674 Validation Reports volumes 1-10.

ENCLOSURE #3

OPG report
“Dose Rate Assessment Considering Lower Aged Fuel in PWMF SB3”
92896-REP-03200-00009

ONTARIOPOWER GENERATION

Report

OPG Proprietary	
Document Number: **92896-REP-03200-00009**	Usage Classification: **N/A**
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Title:
DOSE RATE ASSESSMENT CONSIDERING LOWER AGED FUEL IN PWMF SB3

Dose Rate Assessment Considering Lower Aged Fuel in PWMF SB3

92896-REP-03200-00009 R000
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Revision Summary

Revision Number	Date	Comments
R000	2020-06-12	Initial issue.

1. INTRODUCTION

1.1 Background

Ontario Power Generation's (OPG's) Pickering Nuclear Generating Station (NGS) is located on the north shore of Lake Ontario in the Regional Municipality of Durham. The Pickering Waste Management Facility (PWMF) handles the transfer, processing and storage of Dry Storage Containers (DSCs) containing used fuel discharged from the Pickering NGS units.

The PWMF is part of the larger OPG Pickering site; the location of the PWMF within the Pickering NGS site is shown in Figure 1.

The PWMF site has undergone an orderly development in phases to facilitate the growing number of DSCs over the years. These phases are:

- Phase I: The PWMF Phase I site is located within the Pickering NGS protected area, southeast of Pickering NGS Unit 8, adjacent to the east side of the station security fence. The Phase I site consists of a DSC Processing Building (PB), DSC Storage Buildings (SBs) 1 and 2, and the Retube Components Storage area.
- Phase II: The PWMF Phase II site is located approximately 500 m northeast of the PWMF Phase I site, east of the Pickering NGS powerhouse, within its own protected area in the Pickering Nuclear site. The Phase II site consists of DSC SB3 (see Figure 2 and Figure 3) with provision for future SB4.

The existing operation of the PWMF involves the processing and storage of DSCs containing used fuel with a minimum of ten (10) years of decay. In order to support PWMF operations, an analysis to determine the impacts of loading used fuel cooled for less than ten (10) years is being completed. These lower fuel age DSCs are planned to be stored in SB3.

The existing PWMF Safety Report [1] and the latest safety assessment update [2] have considered the storage of DSCs with a minimum of ten (10) years of decay in SB3. The purpose of this document is to determine the impact, from a dose rate perspective, of storing fuel that has only cooled for six (6) years.

The current report documents the dose rate analysis part of the assessment associated with the storage of the lower fuel age DSCs in SB3. The calculation model was based on the previous shielding assessment documented in Reference [3] with appropriate changes in the DSC loading pattern applied to SB3.

1.2 Scope

This report documents the dose rate assessment for the storage of DSCs with lower fuel age in SB3 at PWMF. The current assessment considers the storage of 100 DSCs containing six (6) year decayed used fuel to replace the equivalent number of existing DSCs stored in SB3. Dose rates at the following locations are calculated and presented:

- Dose rates at and beyond the existing protected area fence surrounding SB3 and SB4;
- At the Pickering NGS property boundary (Montgomery Park Rd);
- At the lakeside exclusion boundary;
- At the Training and Mock-up Building (TMB); and
- At the main aisle way of SB3 in the vicinity of the lower fuel age DSCs.

Note, the limiting dose rates at the above locations are primarily from radiation sources from SB3 and SB4. The contribution of radiation sources from DSCs and Dry Storage Modules (DSMs) stored in the PWMF Phase I site to the direct external radiation field at the limiting locations around the Phase II site are negligible [4]. Therefore, contribution from the Phase I site is not included in the current analysis.

In addition, estimated dose rates near contact[1] and at 1 m from the long side of a single DSC loaded with 230 MWh/kgU fuel bundles with average decay times of 6, 10, 15, 20, 25, 30, 35 and 40 years decay time are reported.

1.3 Quality Assurance

The work was performed by Candu Energy Inc. in accordance with the Quality Assurance (QA) program described in 147-912020-QAP-001 "CANDU Services Projects (CSA Z299 Series)", CE-912020-QAM-002 "Candu Energy Inc. – Quality Assurance Manual" and CE-912020-QAM-003 "Quality Assurance Manual – Analytical, Scientific and Design Computer Programs" to satisfy the QA requirements of the following standards applicable to the scope of work:

- CSA CAN3-Z299.1-85 "Quality Assurance Program Category 1";
- CSA N286-12 "Management System Requirements for Nuclear Facilities"; and
- CSA N286.7-16 "Quality Assurance of Analytical, Scientific and Design Computer Programs for Nuclear Power Plants".

1.4 Terms and Abbreviations

AP	Antero-Posterior
CNSC	Canadian Nuclear Safety Commission
COG	CANDU Owners Group
CSA	Canadian Standards Association
DSC	Dry Storage Container
DSM	Dry Storage Module
ENDF	Evaluated Nuclear Data File
EPB	Enhanced Processing Building
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection
IST	Industry Standard Toolset
MCNP™	Monte Carlo N-Particle Transport
NEW	Nuclear Energy Worker
NGS	Nuclear Generating Station
OPG	Ontario Power Generation
PB	Processing Building
PWMF	Pickering Waste Management Facility
QA	Quality Assurance
RCS	Retube Components Storage
ROT	Rotational
SB	Storage Building
SCALE	Comprehensive modeling and sumulation suite for nuclear safety analysis and design
SSR	Surface Source Read – MCNP option
SSW	Surface Source Write – MCNP option
TMB	Training and Mock-up Building
UFDS	Used Fuel Dry Storage

[1] Contact dose rates were calculated at a distance of 5 cm from the DSC surface.

2. ACCEPTANCE CRITERIA

The radiation safety requirements for the PWMF under normal operation[2] are the following:

- ≤ 10 µSv per year for the general public at, or beyond the Pickering NGS site boundary. This dose rate target is one percent (1%) of the CNSC regulatory dose limit of 1 mSv per year for a member of the public [1].
- ≤ 0.5 µSv/h outside of the protected area fence (boundary of the PWMF licensed facility), based on the 1 mSv/a effective dose limit for non-Nuclear Energy Workers (NEWs) and an occupancy rate of 2000 hours per year [1].

3. METHODOLOGY

Dose rates are calculated for normal operation of the PWMF following the reference methodology for heavily shielded containers [5]. Computer codes used for the dose rate calculations are listed in Section 3.6. Additional discussions on the various aspects of the dose rate calculations are provided in the following subsections.

3.1 General Approach

Dose rate calculations during normal operations follow the OPG reference methodology for heavily shielded containers [5]. The general calculation approach is using the two-stage approach, for both site shielding and single DSC assessments. The main steps in applying the two-stage analysis to DSC problems are:

1. Perform a Stage-1 analysis of a single DSC to capture the photon source escaping from the DSC by using the Surface Source Write (SSW) and Surface Source Read (SSR) options in MCNP. Photons escaping the DSC are recorded as they pass through user-selected planes outside the DSC. Recorded photon information is then used as a boundary source in the Stage-2 calculations. The single-stage analysis is performed for representative source energy groups for an irradiated fuel bundle of a specific decay time and burnup. DSCs containing irradiated fuel of various decay times and burnup are assessed as recommended in the reference methodology [5]. This step has been performed for fuel with ten (10) years decay as part of the work documented in Reference [6].
2. Perform Stage-2 analyses to calculate dose rates near DSCs, within buildings, and around the area outside of buildings. For the Stage-2 modified Phase II site model, MCNP input files from Reference [3] were used as the starting model. The following changes are implemented in the starting model:
   a. The layout of the DSCs in SB3 is modified to replace one hundred (100) DSCs with DSCs containing six (6) year decayed fuel; and
   b. The MCNP tally definitions are modified to include the existing protected area fence, the Pickering NGS property fence, and the SB3 aisle way.

Note that, as indicated in in the shielding assessment for SB4 [3], neutrons are generated in irradiated fuel in addition to gamma radiation. However, due to use of heavy concrete in the design of the DSC, the neutron dose rates outside DSCs are negligible compared to gamma dose rates and therefore neutrons are not included in the current shielding assessment.

[2] As per the wording in Section 4.2 of Reference [1], these requirements are for the operation of the PWMF only and are exclusive of the dose from the Pickering NGS. Additional discussion on the radiation safety requirements and dose rate targets is provided in Reference [1].

3.2 Representation of Geometry in MCNP Models

3.2.1 Stage-1 DSC

The representation of the DSC geometry (internal structures, rebar) and fuel bundles contained therein is described in Reference [4]. For the Stage-1 MCNP simulations, the DSC and fuel bundles were modeled in detail (see Figure 4, Figure 5, and Figure 6). The SSW files generated from the existing Stage-1 calculations [6] for reference used fuel, with a burnup of 230 MWh/kgU and 10 years decay time, are utilized.

3.2.2 Stage-2 DSC

For the Stage-2 MCNP simulations, a simplified DSC model is used, consistent with the models documented in Reference [3]. The density of the homogenized mixture of heavy concrete and rebar is 3.57 g/cm^3. The cavity of the DSC is represented as a single region of homogenized UO_2, Zircaloy cladding, air, and steel with a mixture density of 2.96918 g/cm^3 (see Footnote 3).

This simplification is justified because in the Stage-2 simulations, photons are 'born' from the captured Stage-1 virtual source planes in the air outside of each DSC. Photons entering a DSC in the Stage-2 calculations have a low probability of escaping. As such, there is little benefit in modelling the fine details within a DSC in this stage.

3.2.2.1 Single DSC Model

For the single DSC dose rate calculations, the single DSC model and analysis results from the previous shielding assessment for SB4 [3] are extracted and used in the current work. In the analysis presented in Reference [3], the dose rates are obtained from Stage-2 calculations by applying the existing SSW files as the SSR. Additionally, the DSC is placed on the concrete floor to account for scattering off the floor.

3.2.2.2 PWMF Site Model

The MCNP modelling of the PWMF site and buildings in this analysis is exactly the same as in the previous shielding assessment [3]. A detailed description of the PWMF site MCNP model is given in Reference [6], with the recent changes to the modelling of SB3 and SB4 outlined in Reference [3]. There are no changes to the modelled geometry of the PWMF site for the current analysis.

As part of the PWMF site MCNP model, SB3 currently stores 480 DSCs. One hundred (100) of the stored DSCs are replaced with DSCs containing six (6) year decayed fuel. The physical positions of the DSC arranged in SB3 remains the same as in Reference [3]. Previously, the DSCs in SB3 are assumed to contain used fuel bundles that have decayed for 25 or 30 years. As identified in Section 1.1, 100 of these DSCs are replaced with DSCs containing used fuel bundles that have decayed for 6 years.[4] The loading of the DSCs in SB3 is shown in Figure 7.[5]

The loading of the DSCs in SB4, shown in Figure 8, remains consistent with the shielding assessment for SB4 [3].

3 The MCNP input files are carried-over from the analysis presented in Reference [3]. As such, the material definitions are kept constant with Reference [3] and do not reflect the accuracy to which these values are known or estimated.

4 The 100 replaced DSCs comprise 97 DSCs containing 25 year decayed used fuel and 3 DSCs containing 30 year decayed used fuel.

5 The loading pattern of DSCs in SB3 is proposed to ensure the DSCs containing 6 year decayed used fuel are surrounded by DSCs containing used fuel decayed for longer periods with the intention of minimizing dose rates external to the building. In addition, because DSCs are being transferred out of SB3 to SB4 (e.g. to make room in SB3 to allow younger fuel to be stored), older DSCs will be selected for the transfer into SB4 due to their lower dose rates.

MCNP representations of the DSC layout in SB3 and SB4 are shown in Figure 9 and Figure 10, respectively.

3.3 Wall Openings

The manway doors in SB3 are represented as low-density (0.07536 g/cm^3) steel and the roll-up doors are represented as being open (i.e. as if no door is present), as per Reference [3]. Similarly, a roll-up door on the south wall of SB3 was added as part of the analysis documented in Reference [3] and is included in the current analysis.

3.3.1 Building Walls and Roofs

For SB3, the bulk shielding material is ordinary concrete, except for the building roof, which is made of steel. SB4 is modelled with 22 gauge (0.0759 cm) steel walls and roofs with an ordinary concrete floor. The shielding material, composition, and density are the same as the existing analysis [3] and follow the reference methodology [5].

3.3.2 Ventilation

The existing ventilation designed for the SB3 (Reference [6]) remains as modelled in Reference [3]. SB4 is modelled without ventilation.

3.4 Representation of Materials

The composition and density of materials used in the previous shielding assessment [3] is utilized in the current analysis. A detailed list of material compositions and densities is available in Table 1.

3.5 Variance Reduction

The current work involves deep penetration photon transport and transport of photons over a long distance. As such, a direct simulation (analog MCNP) would be lengthy in computation and impractical. The Stage-1 SSW file generation involves deep penetration shield transport. A “geometry splitting with Russian roulette”[6] variance reduction technique was employed by splitting the shield materials inside a DSC. Stage-1 simulations are not repeated in the current work. For the Stage-2 simulations, the SSW files from the Stage-1 simulation are used as source terms.[7] The Stage-2 simulations involve transport over a long distance. A similar “geometry splitting with Russian roulette” variance reduction technique is employed by splitting the shield material (walls, roofs) or splitting the air between the source and the receptors.

3.6 Representation of Radiation Source Terms

3.6.1 Photon Source Spectra

The source spectra is supplied as input to the MCNP simulations as a distribution of photons as a function of energy. This energy distribution can be provided either as a set of discrete ‘lines’ corresponding to the actual decay emission energies of photons produced from individual radionuclides or as a set of ‘energy’ bins into which the individual photon energies are binned and sampled via a histogram distribution. When the number of radionuclides contributing to the decay photon source term is

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6 In MCNP, particles transported from a region of higher importance to a region of lower importance undergo Russian roulette; that is, some of those particles are stochastically terminated, but the weight of surviving particles is increased.

7 The SSW files are not modified in the Stage-2 MCNP simulations. The surfaces comprising the SSW source are translated (with the TRn card) to each desired location corresponding to each DSC position. The relative intensity / weighting of each instance of the SSW source is then scaled using the SPn card.

small, the discrete photon energy lines are supplied. When the number of radionuclides is large, it is more practical to define the photon source energy in the form of energy bins.

The resolution of the photon decay spectra is generally determined by the limitations of the calculation method, rather than MCNP, as MCNP is able to handle a detailed spectra. In the current analysis, the photon source spectrum is represented using 500 energy groups. Following the approach in Reference [5], this source spectrum was grouped into six energy bands. A separate SSW file was generated for each of the energy bands (Reference [6]).

Decay photons with energy <0.3 MeV do not escape the thick concrete shield of the DSC and their contribution to the dose rate outside of the DSC is negligible. Therefore, it is judged to be acceptable not to sample decay photons with energy <0.3 MeV. Similarly, the population of decay photons with energy >3 MeV is small (< 0.01%) and their percent contribution to the total dose rate outside of the DSC is judged negligible. Thus, these decay photons are not sampled either.

The six energy bands for the SSW files are listed in Table 2. The surface sources for the DSCs at the PWMF were generated using the reference fuel bundle properties [6], these include:

- Pickering-type 28-element fuel bundle;
- Mass of Uranium per bundle is 20.2 kg;
- Exit burnup of 230 MWh/kgU;
- Fuel bundle decay time of 10 years; and
- Fuel bundle power of 373 kW (fission) representing the core average of 100% full power operations.

3.6.2 Spent Fuel Decay Times

The fuel stored in SBs across the PWMF includes seven binned decay times: 10, 15, 20, 25, 30, 35 and 40 years [3]. In addition, a decay time of 6 years will be applied to the 100 replaced DSCs to be stored in SB3. All DSCs in the SBs have different decay times. The DSC loading pattern is determined based on OPG's input. The loading patterns for SB3 and SB4 are provided in Figure 7 and Figure 8 , respectively. The burnup for all decay times is assumed to be the same as the burnup of the reference fuel (i.e., 230 MWh/kgU).

3.6.3 Two-Stage Decay Source Treatment

The SSW files were generated for the reference fuel burnup and decay time. DSCs with different fuel burnup and decay times use the same SSW files. The total source term for SB3, including 480 DSCs of various ages, is weighted using the SPn/TRn cards in the SSR option of the MCNP file. The total weight distribution considers the relative source terms of each DSC based on the characteristics of the stored used fuel compared to those of the reference fuel burnup and decay. The use of the same SSW files assumes that the fine-group photon spectrum in each energy band is identical. The impact of applying the reference fuel spectra to all fuel burnup/decay age combinations has been investigated and documented in Reference [7].[8] The investigation shows that the difference in the group average energies is negligible and has no impact on the calculated dose rates. Therefore, the use of the reference SSW files for other decay times is justified.

[8] The work in Reference [7] was performed for the Western Waste Management Facility, however, the conclusion regarding the application of the reference fuel spectra to all fuel burnup / decay age combinations remains appropriate for the current analysis.

3.6.4 ORIGEN-S Photon Spectrum

The fine-group photon spectrum used in the previous PWMF shielding assessment [3] was generated using the bundle-wise 28-element ORIGEN-S cross-section library provided with the distribution of SCALE. The 28-element Pickering-specific cross-section library was updated in Reference [2] including ring-wise spectra. The cross-section library was further revised in Reference [8].

The revised cross-section library generated in Reference [8] is used in the current analysis to calculate the source terms used in the MCNP dose rate calculation.

3.7 Dose Rate Tallies

MCNP provides several methods of estimating photon fluxes required to calculate dose rates. The track-length estimate (F4) cell tally is simple and reliable for problems where many photon histories pass through the volume of interest. The FMESH tallies are simple and reliable and have similar applications as F4 tallies. The FMESH tallies can be placed at general locations and are useful to show the spatial distribution of dose rates around components or areas. The current scope of work calculations utilizes F4 and FMESH tallies following the two-stage methodology.

The dose rates from a single DSC at near contact and at 1 m from the wide side of a single DSC with 6, 10, 15, 20, 25, 30, 35 and 40 years decay time are reported. Results are discussed in Section 4.1.

Dose rates surrounding SB3 / SB4 resulting from the inclusion of 100 DSCs containing 6 year decayed used fuel are tabulated at the following locations:

- Across the main aisle way of SB3 - results are discussed in Section 4.2

  An FMESH tally (approximately 30 cm x 30 cm x 50 cm) is used to calculate the dose rates across the SB3 aisle way. The mesh tally location across the aisle way of SB3 is shown in Figure 11. Receptor locations are shown in Figure 12 and also listed in Table 3. A sketch of mesh tally locations around SB3/SB4 to calculate the dose rate at the PWMF existing protected area fence is shown in Figure 13.

- At selected dose receptor locations - results are discussed in Section 4.3.1

  FMESH tallies (10 m x 10 m x 2 m rectangular cuboids) are used to calculate the dose rates at the Pickering NGS site boundary (Montgomery Park Rd), the lakeside exclusion zone boundary, and at the TMB. The FMESH tallies are located above the ground at various locations. The lakeside exclusion zone receptors are located 8 m below ground level, the level at which lake water is modelled in MCNP.

- Protected area fence - results are discussed in Section 4.3.2

  An FMESH tally encompassing the area around SB3 / SB4 is used to calculate the dose rates at the protected area fence. The layout of the protected area fence surrounding SB3 and SB4 is given in Reference [9]. The following distances, to the centre of the protected area fence, are adopted in the analysis of the dose rates:

  - North Fence: 15.00 m from the north wall of SB3;
  - East Fence: 15.33 m from the east wall of SB3;
  - South Fence: 96.68 m from the south wall of SB3;
  - West Fence: 18.00 m from the west wall of SB3; and
  - West Fence, extended[9]: 66.00 m from the west wall of SB3.

[9] Distances derived from the dimensions provided in Reference [9].

All cardinal directions are given based on the site construction north (i.e. the south fence is the fence on the construction south side of SB3).

3.8 Nuclear Data

The photoatomic library mcplib04 [10] from the MCNP6 distribution package is utilized. The library is the most up-to-date photoatomic data set in MCNP. It is based on the ENDF/B-VI release 8 nuclear evaluation data.

3.9 Dose Rate Conversion Coefficients

Dose rate conversion values given in ICRP publication 116 [11] are used.

Dose rates are computed using an “Antero-Posterior” (AP) dose conversion curve, which conservatively assumes that personnel are facing the DSCs. Over most of the range of photon energies normally encountered in DSC applications (less than about 10 MeV), the AP dose conversion curves predicts higher dose rates than if other directional conversion curves are assumed, due to the actual configuration of organs and tissues in human bodies. The calculation of dose rates using the AP conversion curves provides a level of inherent conservatism since in practice, there would be no preferred orientation of personnel at most dose locations outside of processing and storage buildings.

In addition, the dose rates are also computed using a “Rotational” (ROT) dose conversion curve, in which a geometry is defined by rotating the body at a uniform rate about its long axis, while irradiating the body by a broad beam of ionising radiation from a stationary source, in this case DSCs, located on an axis at right angles to the long axis of the body.

Dose rates calculated using the AP and ROT dose conversion factors are reported. Compliance to the dose rate acceptance criteria is demonstrated using the ROT dose conversion factor.

3.10 Target Relative Error

MCNP tally results include the relative error corresponding to one standard deviation. These errors cannot be believed reliable (hence neither can the tally itself) unless the error is fairly low. Results with relative errors less than 10% are generally (but not always) reliable for the F4 and FMESH tally types used in this analysis.

The target relative error for the current dose rate assessment is 5%. If there are dose rate values with relative error >5% but <10%, the values may be conditionally accepted if there is an adequate margin to the acceptance criteria. In order to achieve the target relative error, averaging across neighbouring FMESH tally cells is applied at applicable locations of interest.

Results are presented by listing the calculated dose rates from MCNP as the best estimate dose rates and their associated one-sigma uncertainties. Comparison to the acceptance criterion is done using the best estimate + two-sigma uncertainty dose rate.

3.11 Other Options in MCNP

The MCNP photon treatment options such as the upper energy limit for the detailed photon physics model, generation of bremsstrahlung photons with thick-target bremsstrahlung model, coherent Thompson scattering treatment (on), photonuclear particle production (off), photon Doppler energy broadening (on), photo-fission model (no photo-fission prompt gammas) is set to the MCNP default setting.

3.12 Computer Codes

3.12.1 MCNP

Computer Program Name	MCNP [12]
Code Version	6.1
Operating System	Linux 64 bit

Code description:

MCNP is a general-purpose Monte Carlo code that can be used for neutron, photon, or coupled neutron/photon/electron transport. The code treats an arbitrary three-dimensional configuration of materials in geometric cells bounded by 1st and 2nd degree surfaces and 4th degree elliptical tori. Point-wise cross-section data are used. For neutrons, all reactions given in a particular cross-section evaluation (e.g. the ENDF Evaluated Nuclear Data File) are accounted for. Thermal neutrons are described by both the free gas and scattering kernel S(α,β) models. For photons, the code accounts for incoherent and coherent scattering, the possibility of fluorescent emission after photoelectric absorption, and absorption in electron positron pair production. The mcplib04 photon cross-section library from the MCNP distribution package [10] is used for gamma photon transport calculations.

Use of code:

For the current analysis, the MCNP code is used to calculate the gamma dose rates at various locations in the PWMF site.

Validation and code applicability:

The use of code described above is within the validation range of applicability described below.

The MCNP code has been used worldwide for neutron, photon, and electron transport calculations. MCNP validation results are available from the following documents provided by the code developer:

- LA-UR-03-9032, Bibliography of MCNP Verification & Validation: 1990-2003
- LA-UR-04-8965: Bibliography of MCNP Verification & Validation: 2004
- LA-UR-02-0878: Validation Suites for MCNP, Proc. of the American Nuclear Society, Radiation Protection and Shielding Division.
- LA-UR-12-26307: V&V of MCNP and Data Libraries at Los Alamos.

MCNP has been used to perform the dose rate calculations for the Western, Darlington, and Pickering waste management facilities. The reference methodology described in Reference [5] is applied. Reference [5] also discusses the validation and benchmarking of the MCNP with respect to dose rate analysis involving DSCs.

3.12.3 SCALE

Computer Program Name	SCALE [13]
Code Version	6.1 (COG IST)
Operating System	Linux 64 bit

Code description:

The ORIGEN-S module of SCALE is employed in the current analysis.

ORIGEN-S is the depletion module to calculate neutron activation, actinide transmutation, fission product generation, and radiation source terms. It applies a matrix exponential expansion model to calculate time-dependent concentrations, activities, and radiation source terms for a large number of isotopes simultaneously generated or depleted by neutron transmutation, fission, and radioactive decay. The ORIGEN-S libraries include nuclear data for 2226 nuclides produced by neutron activation, fission, and decay. All decay data are based on the ENDF/B-VII.0.

Use of code:

The ORIGEN-S module is used to provide the gamma source terms for use in MCNP dose rate calculations. The cross-section library recently generated for the bundle-wise cross-section library in Reference [8] is used for this analysis.

Validation and code applicability:

For the use of the code described above, the ORIGEN-S code has also been validated for various nuclear reactor types, including CANDU reactors. A list of publicly available documents on the ORIGEN-S validation is available from the SCALE code developer website: https://www.ornl.gov/scale/scale/spent-fuel-isotopic-characterization

3.13 Analysis Assumptions

The assumptions in the current analysis are the same are those adopted in the SB4 shielding assessment [3]. The list of assumptions and the justification of each assumption are listed below.

Assumption	Justification of Assumption
100 DSCs containing 6 year fuel are incorporated in the loading pattern of SB3.	The total number of DSCs containing 6 year decayed used fuel to be stored in SB3 is expected to be equal to or less than 100. Therefore, consideration of 100 DSCs is bounding in the dose rate estimation.
All personnel doors and rollup doors are assumed open (air material composition is applied at the location of the door)	Provides conservatism in the dose rate estimation.
The DSC placement at the east and west of the SB4 follows a uniform gap between the DSCs. However, the north-south gap for the centre row is about 55 cm more than the rest of the rows in SB4 (see Reference [3]).	The assumption has no impact on the final results and is consistent with previous analyses (see References [3] and [6]).

Assumption	Justification of Assumption
DSCs with different fuel burnup and decay times use the same SSW files in the MCNP calculations. The use of the same SSW files assumes that the fine-group photon spectrum in each energy band is identical.	The impact of applying the reference fuel spectra to all fuel burnup/decay age combinations has been investigated and documented in Reference [7]. The investigation shows that the difference in the group average energies is negligible and has no impact on the calculated dose rates.

4. RESULTS

Best estimate dose rate values are presented along with the associated 1σ uncertainty (the statistical uncertainty quoted by MCNP). Compliance to the acceptance criteria is evaluated using the best estimate + 2σ uncertainty values. The reported dose rates do not include the natural background contribution, which is approximately 0.2 µSv/h based on Reference [1].[10]

4.1 Dose Rates from Single DSC

The calculated dose rates from a single DSC loaded with 6 year decayed used fuel (230 MWh/kgU burnup) are listed in Table 4.

The calculated dose rates on the long side of a DSC as a function of used fuel decay time are given in Table 5 and shown in Figure 14. The dose rates are presented for used fuel decay times between 6 years and 40 years.

For DSCs loaded with reference used fuel bundles (decayed by 10 years or older), the measured contact dose rates to date are about 9 to 13 µSv/h [1]. This compares with the calculated estimate of the near contact (at the DSC long side) dose rate of 37.9±0.2 µSv/h for reference used fuel (decayed by 10 years). At 1 m distance, measured dose rates are about 5 to 7 µSv/h [1], compared with calculated dose rate estimates of 20.0±0.1 µSv/h.

In the current analysis, the estimated dose rates from a DSC containing 6 years decayed used fuel are 97.4±2.6 µSv/h at near contact and 51.2±0.9 µSv/h at 1 m. These dose rates are a factor of approximately 2.6 times larger than the dose rates calculated for used fuel decayed 10 years. Therefore, it is expected that the measured dose rates for DSCs containing 6 year decayed used fuel will increase by a similar factor (2.6x) compared to the dose rates measured from the DSCs containing the reference used fuel.

While the calculated dose rate in all individual energy groups (G00 – G05) increases for the 6 year decayed used fuel as a result of the shorter decay time, the largest relative increase is seen in energy group G05. With respect to 10 year decayed used fuel, the intensity of the photon spectrum for energy group G05 increases approximately 25 times for the 6 year decay used fuel. The increase is driven by the greater amount of Rh-106 (half-life of approximately 30 seconds) and Pr-144 (half-life of approximately 17 minutes) in the 6 year decayed used fuel.

10 The natural background contribution of 0.2 µSv/h includes all sources of background radiation, such as internal doses from K-40, cosmic radiation, and radon doses in the home. The TLDs used for on-site measurements will not include all these sources, so it is expected that the background contribution to TLD results is much lower than 0.2 µSv/h.

4.2 Dose Rates across the SB3 Main Aisle Way

The dose rate profile across the SB3 main aisle way was evaluated for the DSC loading pattern[11] including the 100 DSCs containing 6 year decayed used fuel. The calculated dose rate profile across the SB3 aisle way is shown in Figure 15. The profile was calculated for a location near the centre of where the DSCs containing 6 year decayed used fuel will be stored. The maximum estimated dose rate across the aisle way is 13.6±0.5 µSv/h. The average dose rate in the main aisle way at distances 5 m or more away from the DSCs is estimated to be 4.7±0.1 µSv/h.

These estimated dose rates across the SB3 main aisle way are significantly less than the maximum (33.9±1.6 µSv/h) and average (9.4±0.2 µSv/h) dose rates calculated for the SB4 main aisle way [3]. The difference in dose rates across the SB3 and SB4 aisles results from the different decay age used fuel stored in the two buildings. Compared to SB3, SB4 contains a larger portion of lower decay age used fuel (10 – 20 years) which contributes to a higher dose rate. Further, the loading pattern for SB4 has a larger amount of DSCs with low decay age fuel bordering the main aisle way which, as seen in Table 5, have larger dose rates than the 25 year decayed used fuel stored along the main aisle way in SB3.

The proposed loading pattern of SB3 (see Figure 7) has the aisle way lined with DSCs containing 25 year decayed used fuel. When compared to the dose rates from a single DSC containing 6 year decayed used fuel, the calculated dose rates across the main aisle way are significantly lower. The DSCs containing 25 year decayed used fuel lining the aisle way provide shielding from the DSCs with the lower fuel decay age.

4.3 Dose Rates around PWMF

4.3.1 Dose Rate at Selected Receptors

The dose rates at selected receptor locations were calculated based on the DSCs stored in SB3. Table 6 shows the calculated dose rates for the existing SB3 DSC loading pattern (analyzed in Reference [3]) compared to the proposed loading pattern for 100 DSCs containing 6 year decayed used fuel. The calculated dose rates at all receptor locations increase with the storage of lower fuel age in SB3. This increase in dose rate is expected as the dose rates from DSCs containing 6 year decayed used fuel are larger than the dose rates of the replaced DSCs from SB3 which contain used fuel decayed for longer periods of time (see Section 4.1 and Table 5).

The total dose rates at the selected receptor locations resulting from the DSCs stored in SB3 and SB4 are given in Table 7. The contribution from SB3 includes the 100 DSCs containing 6 year decayed used fuel. The dose rate at the Montgomery Park Rd Pickering NGS site boundary (PW24) represents the Pickering NGS site boundary fence.[12] The estimated dose rate at the Montgomery Park Rd site boundary (PW24) receptor location from SB3 and SB4 is $(1.7\pm0.1)\times10^{-3}$ µSv/h. Based on a yearly occupancy of 2000 hours, the annual dose at the Montgomery Park Rd site boundary is 3.6 µSv/a (best estimate + 2σ uncertainty).

Comparison against the acceptance criteria is given in Table 8. The AP dose conversion factor is applied in calculations for dose receptor locations within the PWMF protected area fence. The ROT[13] dose conversion factor is applied for calculation for the remaining receptor locations. It is shown that, with the inclusion of 100 DSCs containing 6 year decayed used fuel in SB3, the estimated dose rates and annual doses are within the acceptance criteria.

[11] The DSC loading pattern for SB3 is provided in Figure 7.

[12] As part of the analysis document in Reference [3], receptor location PW24 was shifted to represent the Pickering NGS site boundary fence instead of then the walking path directly east of the fence.

[13] In practice, there would be no preferred orientation of personnel at most dose locations outside of the processing and storage buildings. As such, the ROT dose conversion factor would be appropriate at such locations.

4.3.2 Dose Rate at the Existing Protected Area Fence

The PWMF protected area fence is shown in Figure 3. The distances between the protected area fence and SB3 are given in Section 3.7. An FMESH tally in MCNP with large mesh voxel volumes[14] was used to calculate the dose rate across and beyond the protected fence area (mesh tally area shown in Figure 13).

The dose rates are calculated using the ROT dose conversion factor and provide the dose rate profile at and beyond the protected area fence. The contribution to the dose rates from the DSCs stored in SB3 is calculated as part of the current analysis. The analysis presented in Reference [3] provides the contribution to the dose rate from the DSCs stored in SB4. The maximum estimated dose rates (best estimate + 2σ uncertainty) along the protected area fence, considering the contribution form DSCs stored in both SB3 and SB4, are shown in Table 9.

Along sections of the east, south, and west protected area fence the calculated dose rate exceeds the 0.5 µSv/h acceptance criterion. A representation of these locations is provided in Figure 16. The majority of the dose rate at the areas exceeding the acceptance criterion is due to the DSCs stored in SB4. The distance from the existing protected area at which the dose rate would fall below the acceptance criterion is specified in Table 9.

5. CONCLUSIONS

With respect to the normal operation of SB3 at the PWMF, the inclusion of 100 DSCs containing 6 year decayed used fuel does not pose an unacceptable risk to workers or members of the public. The external radiation exposure at the TMB and the public dose at the site boundary remain below the acceptance criteria outlined in Section 2. The dose rates within SB3 are not adversely affected by the storage of 100 DSCs containing 6 year decayed used fuel and remain comparable to those calculated for other DSC storage buildings ([1]). While dose rates at some locations along the existing protected area fence are over 0.5 µSv/h, the distances beyond the fence to where the dose rates fall below the 0.5 µSv/h acceptance criterion have been provided (see Table 9). It should be noted that the majority of the dose rates at the fence locations that exceed 0.5 µSv/h are from PWMF SB4, and not from the 6 year old fuel in SB3. The risk to workers is low, and, if necessary, other site fences can be used as boundaries at which the target of 0.5 µSv/h can be applied.

[14] FMESH tally voxels are 2 m x 2 m x 2 m in size.

6. REFERENCES

[1] Ontario Power Generation, "Pickering Waste Management Facility Safety Report", 92896-SR-01320-10002 R005, November 2013.

[2] Ontario Power Generation. "Pickering Waste Management Facility Safety Assessment Update", 92896-REP-01320-00005 R002, August 2018.

[3] Ontario Power Generation, "Shielding Assessment for PWMF Storage Building SB4", 92896-REP-03200-00008 R000, June 2019.

[4] Ontario Power Generation, "PMWF Holistic Shielding Analysis and Optimization Study", 92896-REP-03200-00003 R000, August 2016.

[5] Ontario Power Generation, "Reference Nuclear Waste Shielding Analysis Methodology for Heavily Shielding Containers", W-REP-03200-00002 R002, December 2018.

[6] Ontario Power Generation, "Assessment of Outdoor Storage of DSCs at the PWMF", 92896-REP-03200-00007 R000, June 2018.

[7] Ontario Power Generation, "Unshielded DSC Dose Rate Parametric Study", W-REP-03200-00003 R000, June 2018.

[8] Candu Energy Inc., "Impact of Bug Reported in CANDU Burnup-Dependent Neutron Cross-Section Libraries Generated with TRITON version SCALE 6.1.3 on PWMF Safety Assessment", 19-CEOPG-19-0014L, October 2018.

[9] Ontario Power Generation, "Storage Building 3 Architectural Site Plan", 92896-DRAW-29651-10075 R000, March 2009.

[10] LA-UR-03-1019 "Photoatomic Data Library MCPLIB04: A New Photoatomic Library Based On Data from ENDF/B-VI Release 8", 2003.

[11] International Commission on Radiological Protection, "Conversion Coefficients for Radiological protection Quantities for External Radiation Exposures", ICRP Publication 116, 2010.

[12] MCNP: Monte Carlo N-Particle Transport Code version 6.1. Available from Radiation Safety Information Computational Center as code package CCC-810.

[13] SCALE 6.1: A Comprehensive Modeling and Simulation Suite for Nuclear Safety Analysis and Design: includes ORIGEN, version 6.1, available from Radiation Safety Information Computational Center as code package CCC-785.

Table 1 Stage-2 MCNP Material Compositions [3]

Material	Density (g/cm^3)	Element	Un-normalized Weight Fractions
DSC Homogenized Source	2.96918	Oxygen	0.23636
		Iron	2.24677
		Zirconium	0.18575
		Uranium	0.30031
ASTM A516 Grade 70 Steel	7.85	Carbon	0.27
		Silicon	0.4
		Phosphorus	0.025
		Sulfur	0.025
		Manganese	1.2
		Iron	98.08
Dry Air at 35ºC	1.1214E-03	Hydrogen	8.80E-07
		Helium	5.20E-06
		Carbon	1.10E-04
		Nitrogen	0.780851
		Oxygen	0.209682
		Neon	1.82E-05
		Argon	9.33E-03
		Xenon	1.00E-07
High Density Concrete with Homogenized Rebar	3.57	Hydrogen	0.34
		Carbon	0.39
		Oxygen	50.18
		Magnesium	1.1
		Aluminium	1.57
		Silicon	2.56
		Calcium	6.86
		Chromium	5.84
		Iron	31.15
Concrete	2.35 (Normal) 1.175 (Hollow Concrete Block) 2.08 (Grout Concrete)	Hydrogen	0.56
		Oxygen	49.83
		Sodium	1.71
		Magnesium	0.24
		Aluminium	4.56
		Silicon	31.58
		Sulfur	0.12
		Potassium	1.92
		Calcium	8.26
		Iron	1.22

Material	Density (g/cm^3)	Element	Un-normalized Weight Fractions
Ground - Sand	1.6	Oxygen	53.26
		Silicon	46.74
Fiberglass Insulation	0.03	Oxygen	46.14
		Fluorine	0.7
		Sodium	10.53
		Magnesium	1.51
		Aluminium	0.318
		Silicon	33.66
		Calcium	7.15
Rockwool Insulation	0.1	Oxygen	41.72
		Sodium	1.699
		Aluminium	3.45
		Silicon	24.74
		Phosphorus	0.0655
		Potassium	1.303
		Calcium	21.64
		Titanium	0.306
		Manganese	0.0465
		Iron	1.82
Aluminium	0.124876 (Homogenized Louvres)	Aluminium	1
High Density Concrete without Rebar	3.5	Hydrogen	0.35
		Carbon	0.4
		Oxygen	50.19
		Magnesium	1.13
		Aluminium	1.6
		Silicon	2.61
		Calcium	7
		Chromium	5.95
		Iron	29.77
Water	1.0	Hydrogen	0.11191
		Oxygen	0.88809

Table 2 Energy Bands for SSW / SSR Surface Sources in MCNP

Energy Group	Photon Energy Band (MeV)
00	0.30 ≤ E < 0.65
01	0.65 ≤ E < 1.00
02	1.00 ≤ E < 1.25
03	1.25 ≤ E < 1.50
04	1.50 ≤ E < 2.00
05	2.00 ≤ E < 3.00

Table 3 Dose Receptor Locations[15]

Dose Point #	X (cm)	Y (cm)	Z (cm)	Description
PW10	2726	17246	1319	1ft below TMB roof peak (height 41 ft above TMB floor)
PW24	38800	12380	100	Montgomery Park Rd turnaround
PW26	28700	33330	400	Bend in bike path northeast of PWMF Phase II
LS03	-20009	-81613	-700	Off shoreline
LS04	16230	-57143	-700	Off shoreline
LS05	32391	-32700	-700	Lake 282 m off shoreline
LS06	37411	-18888	-700	Lake 144 m off shoreline
LS07	40208	-4460	100	Lake, where shoreline intersects with land site boundary
Figure 11	-	-	100	Mesh tally location across the aisle way in SB3
Figure 13	-	-	100	Mesh tally locations around SB3/4 (green overlay)

15 The origin location (x,y,z) = (0,0,0) corresponds to a location near the centre of the array of DSCs stored in SB4.

Table 4 Calculated Dose Rate (µSv/h) vs. Distance from a Single DSC Containing 6 Year Decayed Used Fuel

Distance From Surface (cm)	Dose Rate (µSv/h)		
	Long Side	Short Side	Top
Near Contact[a]	97.4	86.2	70.5
50	77.4	62.7	49.8
100	51.2	42.9	n/a[b]
150	37.7	29.1	17.0
200	27.7	20.7	10.8
250	23.7	15.5	10.5
300	17.4	12.5	6.4
350	12.8	10.5	5.4
400	10.4	9.0	4.1
450	8.9	6.7	3.2
500	7.2	6.0	2.1

Notes:

a) Contact dose rates were calculated at a distance of 5 cm from the DSC surface.

b) The dose rate at 100 cm from the top of the DSC surface is excluded as the associated statistical uncertainty is significantly larger than the 10% target presented in Section 3.10.

Table 5 Calculated Dose Rate (μSv/h) vs. Distance from a Single DSC (Long Side) at Various Decay Times

	Used Fuel Bundle Decay Time (year)								
Distance (cm)	**6 y**	**10 y**	**15 y**	**20 y**	**25 y**	**30 y**	**35 y**	**40 y**	**Maximum 1σ Uncertainty[b]**
Near Contact[a]	97.4	37.9	26.6	21.0	17.1	14.2	11.9	10.1	2.7%
50	77.4	29.0	20.3	16.0	13.0	10.8	9.1	7.7	2.7%
100	51.2	20.0	14.1	11.1	9.0	7.5	6.3	5.4	1.7%
150	37.7	14.4	10.1	7.9	6.4	5.3	4.5	3.8	2.6%
200	27.7	10.6	7.4	5.8	4.7	3.9	3.3	2.8	3.4%
250	23.7	8.3	5.7	4.5	3.7	3.0	2.6	2.2	9.7%
300	17.4	6.4	4.5	3.5	2.8	2.4	2.0	1.7	5.5%
350	12.8	5.1	3.6	2.8	2.3	1.9	1.6	1.4	2.8%
400	10.4	4.2	2.9	2.3	1.9	1.6	1.3	1.1	2.6%
450	8.9	3.5	2.4	1.9	1.6	1.3	1.1	0.9	4.8%
500	7.2	2.9	2.0	1.6	1.3	1.1	0.9	0.8	3.4%

Notes:

a) Contact dose rates were calculated at a distance of 5 cm from the DSC surface.

b) The uncertainty listed is the maximum uncertainty in the dose rate across all decay times for a given distance.

Table 6 Dose Rate Contribution at Receptor Locations from DSCs Stored in SB3

	Existing DSC Loading [3]		DSC Loading with 6 Year Decayed Used Fuel		Ratio of Best Estimate Dose Rates
Dose Receptor	**Best Estimate (μSv/h)**	**1σ Uncertainty (relative)**	**Best Estimate (μSv/h)**	**1σ Uncertainty (relative)**	
PW10	5.27E-02	3%	7.27E-02	2%	1.38
PW24	4.23E-04	2%	7.36E-04	2%	1.74
PW26	4.62E-04	2%	7.90E-04	2%	1.71
LS03	8.33E-07	4%	2.59E-06	5%	3.11
LS04	1.16E-05	3%	3.09E-05	4%	2.66
LS05	7.13E-05	3%	1.66E-04	3%	2.33
LS06	1.54E-04	2%	3.01E-04	2%	1.96
LS07	2.72E-04	2%	5.05E-04	2%	1.86

Table 7 Dose Rates (µSv/h) from SB3 and SB4

		Contribution from DSCs in SB3		Contribution from DSCs in SB4 [3]		Contribution from SB3 and SB4		
Dose Receptor	Dose Conversion Factor	Best Estimate (µSv/h)	1σ Uncertainty (relative)	Best Estimate (µSv/h)	1σ Uncertainty (relative)	Best Estimate (µSv/h)	1σ Uncertainty (relative)	Best Estimate + 2σ Uncertainty (µSv/h)
PW10	AP	7.27E-02	2%	1.96E-02	4%	9.23E-02	2%	9.61E-02
PW24	ROT	7.36E-04	2%	9.64E-04	4%	1.70E-03	2%	1.78E-03
PW26	ROT	7.90E-04	2%	4.76E-04	3%	1.27E-03	1%	1.30E-03
LS03	ROT	2.59E-06	5%	7.20E-06	6%	9.79E-06	5%	1.07E-05
LS04	ROT	3.09E-05	4%	9.39E-05	4%	1.25E-04	3%	1.33E-04
LS05	ROT	1.66E-04	3%	4.22E-04	5%	5.88E-04	4%	6.32E-04
LS06	ROT	3.01E-04	2%	6.77E-04	2%	9.78E-04	2%	1.01E-03
LS07	ROT	5.05E-04	2%	1.05E-03	4%	1.55E-03	3%	1.64E-03

Table 8 Annual Dose Rates from SB3 and SB4

Dose Point	Best Estimate + 2σ Uncertainty (μSv/h)	Dose Conversion Factor	Occupancy (hours)	Annual Dose based on Occupancy[a] (μSv/a)	Acceptance Criterion
PW10	9.61E-02	AP	2000	192.29	0.5 μSv/h (1000 μSv/a)[b]
PW24	1.78E-03	ROT	2000	3.56	10 μSv/a (1% of public dose limit)
PW26	1.30E-03	ROT	2000	2.61	
LS03	1.07E-05	ROT	1000	0.01	
LS04	1.33E-04	ROT	1000	0.13	
LS05	6.32E-04	ROT	1000	0.63	
LS06	1.01E-03	ROT	1000	1.01	
LS07	1.64E-03	ROT	1000	1.64	

Notes:

a) The presented annual doses include only the contribution from SB3 and SB4. Contribution from other PWMF radiation sources is not included.

b) 1000 μSv/a is the prorated annual dose based on the acceptance criterion of 0.5 μSv/h and 2000 hours occupancy.

Table 9 Dose Rates at Phase II Protected Area Fence from DSCs in SB3 and SB4

Protected Area Fence[a]	Distance From the Edge of SB3 to the Protected Area Fence[b] (m)	Maximum Dose Rate Along Protected Area Fence from DSCs Stored in SB3[c,d] (µSv/h)	Maximum Dose Rate Along Protected Area Fence from DSCs Stored in SB3 and SB4[c,d,e] (µSv/h)	Distance[f] Beyond Existing Protected Area Fence where Dose Rate ≤ Acceptance Criterion (m)	Acceptance Criterion
North	15.00	0.21	0.21[g]	-	0.50 µSv/h
South	96.68	0.02	0.71	7	
East	15.33	0.14	0.56	3	
West	18.00	0.13	0.85	7	
West (extended)	66.00	0.03	0.16	-	

Notes:

a) Directions correspond to the construction site cardinal directions.

b) Distances derived from the dimensions provided in Reference [9].

c) Presented dose rates are the Best Estimate + 2σ uncertainty.

d) The presented dose rates include only the contribution from DSCs stored in SB3 and SB4. Contribution from other PWMF radiation sources is not included.

e) The maximum dose rate from SB3 along the protected area fence occurs at different locations than for the maximum dose rate from SB3 and SB4.

f) Distances are estimated based on the FMESH tally voxel size of 2 m x 2 m x 2 m. A representation of the locations the dose rate exceeds the acceptance criterion is shown in Figure 16.

g) The contribution to the dose rate at the north fence from DSCs stored in SB4 was not calculated as part of the analysis in Reference [3].

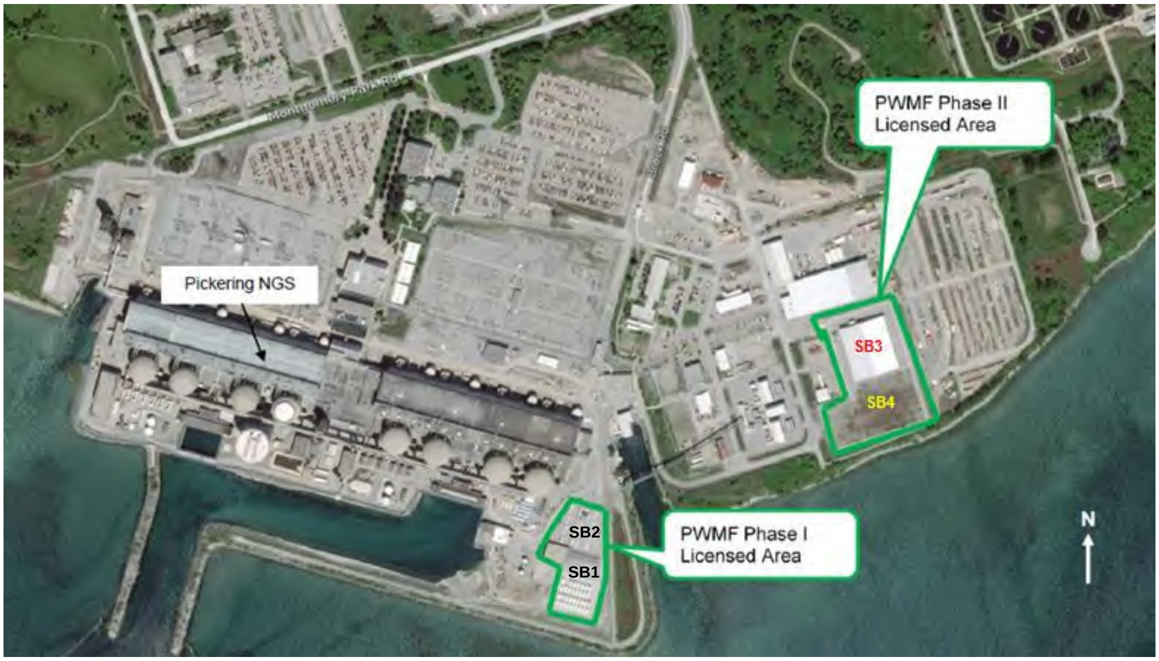

Figure 1 Aerial View of the PWMF Site

Figure 2 PWMF Layout for Current SB3 and Future SB4

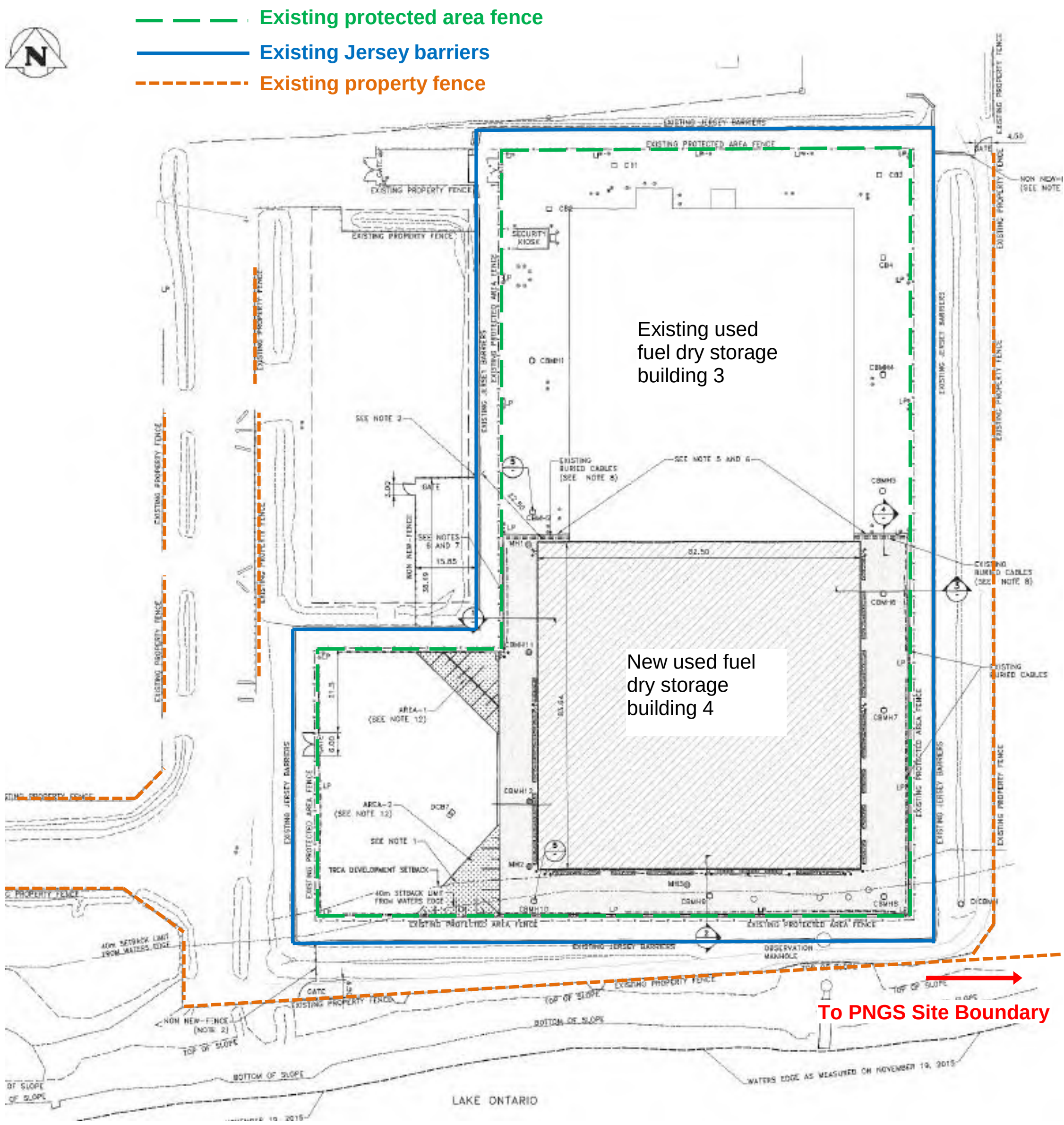

Figure 3 PWMF Phase II Protected Area Fence [3]

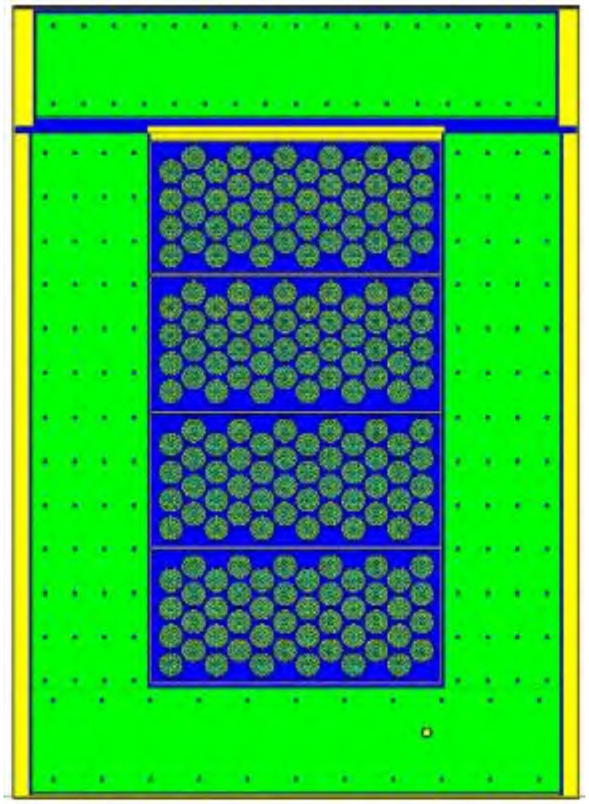

Figure 4 MCNP Representation of a Vertical Slice through a DSC Showing Used Fuel

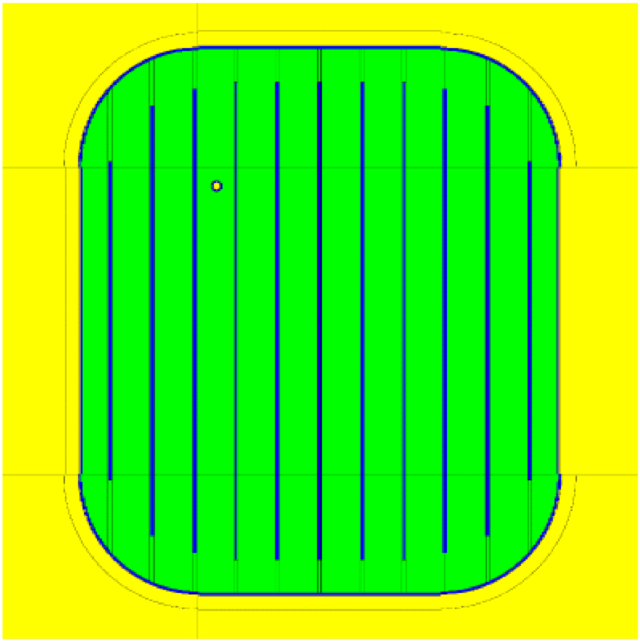

Figure 5 MCNP Representation of a Horizontal Slice through a DSC Showing Rebar Present in the DSC Base

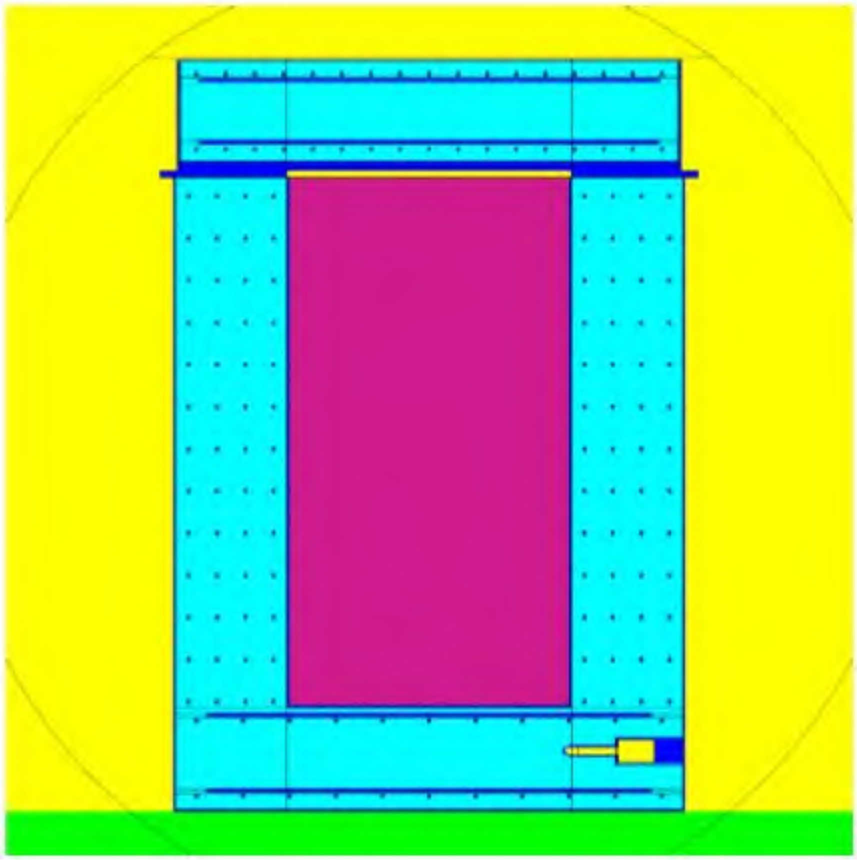

Figure 6 MCNP Representation of a Vertical Slice through a DSC Showing the Homogenized Used Fuel Region

30	30	30	30	25	25	25	25	25	25
30	30	30	30	25	25	25	25	25	25
30	30	30	30	25	25	25	25	25	25
30	30	30	30	25	25	25	25	25	25
30	30	30	30	25	25	25	25	25	25
30	30	30	30	25	25	25	25	25	25
30	30	30	25	25	25	25	25	25	25
30	30	30	25	25	25	25	25	25	25
30	30	30	25	25	25	25	25	25	25
30	30	30	25	25	25	25	25	25	25
30	30	30	25	25	25	25	25	25	25
30	30	30	25	25	25	25	25	25	25
30	30	30	6	6	6	6	**25**	**25**	**25**
30	30	30	6	6	6	6	6	6	**25**
30	30	30	6	6	6	6	6	6	**25**
30	30	30	6	6	6	6	6	6	**25**
30	30	30	6	6	6	6	6	6	**25**
30	30	30	6	6	6	6	6	6	**25**
30	30	30	6	6	6	6	6	6	**25**
30	30	30	6	6	6	6	6	6	**25**
30	30	30	6	6	6	6	6	6	**25**
30	30	30	30	25	25	25	25	25	25
30	30	30	30	25	25	25	25	25	25
30	30	30	30	25	25	25	25	25	25

25	25	25	25	25	25	25	25	25	25
25	25	25	25	25	25	25	25	25	25
25	25	25	25	25	25	25	25	25	25
25	25	25	25	25	25	25	25	25	25
25	25	25	25	25	25	25	25	25	25
25	25	25	25	25	25	25	25	25	25
25	25	25	25	25	25	25	25	25	25
25	25	25	25	25	25	25	25	25	25
25	25	25	25	25	25	25	25	25	25
25	25	25	25	25	25	25	25	25	25
25	25	25	25	25	25	25	25	25	25
25	25	25	25	25	25	25	25	25	25
25	25	25	25	25	25	25	25	25	25
25	6	6	6	6	6	6	25	25	25
25	6	6	6	6	6	6	25	25	25
25	6	6	6	6	6	6	25	25	25
25	6	6	6	6	6	6	25	25	25
25	6	6	6	6	6	6	25	25	25
25	6	6	6	6	6	6	25	25	25
25	6	6	6	6	6	6	25	25	25
25	6	6	6	6	6	6	25	25	25
25	25	25	25	25	25	25	25	25	25
25	25	25	25	25	25	25	25	25	25
25	25	25	25	25	25	25	25	25	25

Values shown in the figure correspond to the DSC decay time in years

Figure 7 SB3 Loading Pattern[16]

16 19 DSCs to be moved back to SB3, after loading the DSCs containing 6 year decayed used fuel, into locations indicated in bold.

35	20	20	20	20	20	20	20	20	20	20	20	20
35	20	15	15	10	10	10	10	10	10	10	10	10
35	20	15	15	10	10	10	10	10	10	10	10	10
35	20	15	15	10	10	10	10	10	10	10	10	10
35	20	15	15	10	10	10	10	10	10	10	10	10
35	20	15	15	10	10	10	10	10	10	10	10	10
35	20	15	15	10	10	10	10	10	10	10	10	10
35	20	15	15	10	10	10	10	10	10	10	10	10
35	20	15	15	10	10	10	10	10	10	10	10	10
30	20	15	15	10	10	10	10	10	10	10	10	10
30	20	15	15	10	10	10	10	10	10	10	10	10
30	20	15	15	10	10	10	10	10	10	10	10	10
30	20	15	15	10	10	10	10	10	10	10	10	10
30	20	15	15	10	10	10	10	10	10	10	10	10
30	20	15	15	10	10	10	10	10	10	10	10	10
30	20	15	15	10	10	10	10	10	10	10	10	10
30	20	15	15	10	10	10	10	10	10	10	10	10
30	20	15	15	10	10	10	10	10	10	10	10	10
30	20	15	15	10	10	10	10	10	10	10	10	10
30	20	15	15	15	15	15	15	15	15	15	15	15
30	20	15	15	15	15	15	15	15	15	15	15	15
40	20	15	15	15	15	15	15	15	15	15	15	15
40	20	20	20	20	20	20	20	20	20	20	20	20
40	20	20	20	20	20	20	20	20	20	20	20	20
40	35	35	35	35	35	35	35	35	35	35	35	40
40	40	40	40	40	40	40	40	40	40	40	40	40

20	20	20	20	20	20	20	20	20	25	40
10	10	10	10	10	15	15	15	20	25	40
10	10	10	10	10	15	15	15	20	25	40
10	10	10	10	10	15	15	15	20	25	40
10	10	10	10	10	15	15	15	20	25	40
10	10	10	10	10	15	15	15	20	25	40
10	10	10	10	10	15	15	15	20	25	40
10	10	10	10	10	15	15	15	20	25	40
10	10	10	10	10	15	15	15	20	25	40
10	10	10	10	10	15	15	15	20	25	40
10	10	10	10	10	15	15	15	20	25	40
10	10	10	10	10	15	15	15	20	25	40
10	10	10	10	10	15	15	15	20	25	40
10	10	10	10	10	15	15	15	20	25	40
10	10	10	10	10	15	15	15	20	25	40
10	10	10	10	10	15	15	15	20	25	40
10	10	10	10	10	15	15	15	20	25	40
10	10	10	10	10	15	15	15	20	25	40
10	10	10	10	10	15	15	15	20	25	40
15	15	15	15	15	15	15	15	20	25	40
15	15	15	15	15	15	15	15	20	25	40
15	15	15	15	15	15	15	15	20	25	40
20	20	20	20	20	20	20	20	20	25	40
20	25	25	25	25	25	25	25	25	25	40
40	35	35	40	40	40	40	40	40	40	40
40	40	40	40	40	40	40	40	40	40	40

Values shown in the figure correspond to the DSC decay time in years

Figure 8 SB4 Loading Pattern [3]

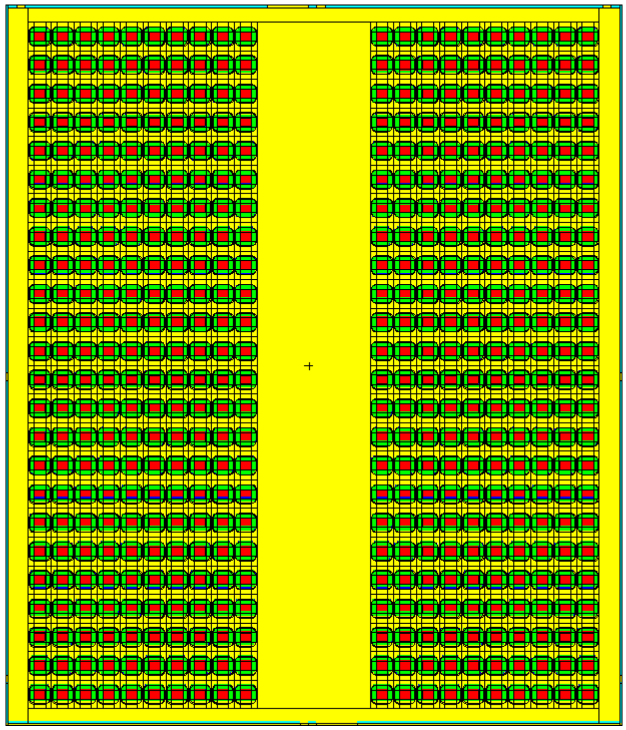

Figure 9 MCNP Representation of the DSC Layout in SB3

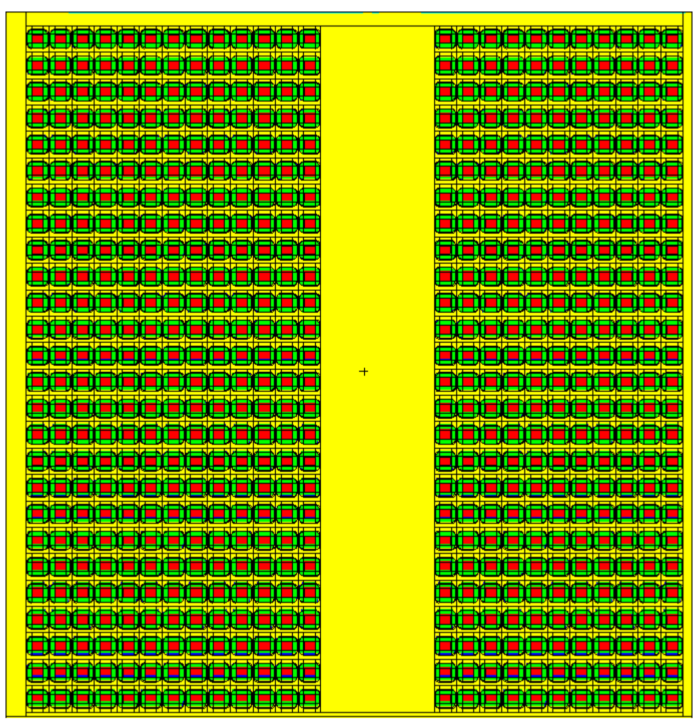

Figure 10 MCNP Representation of the DSC Layout in SB4

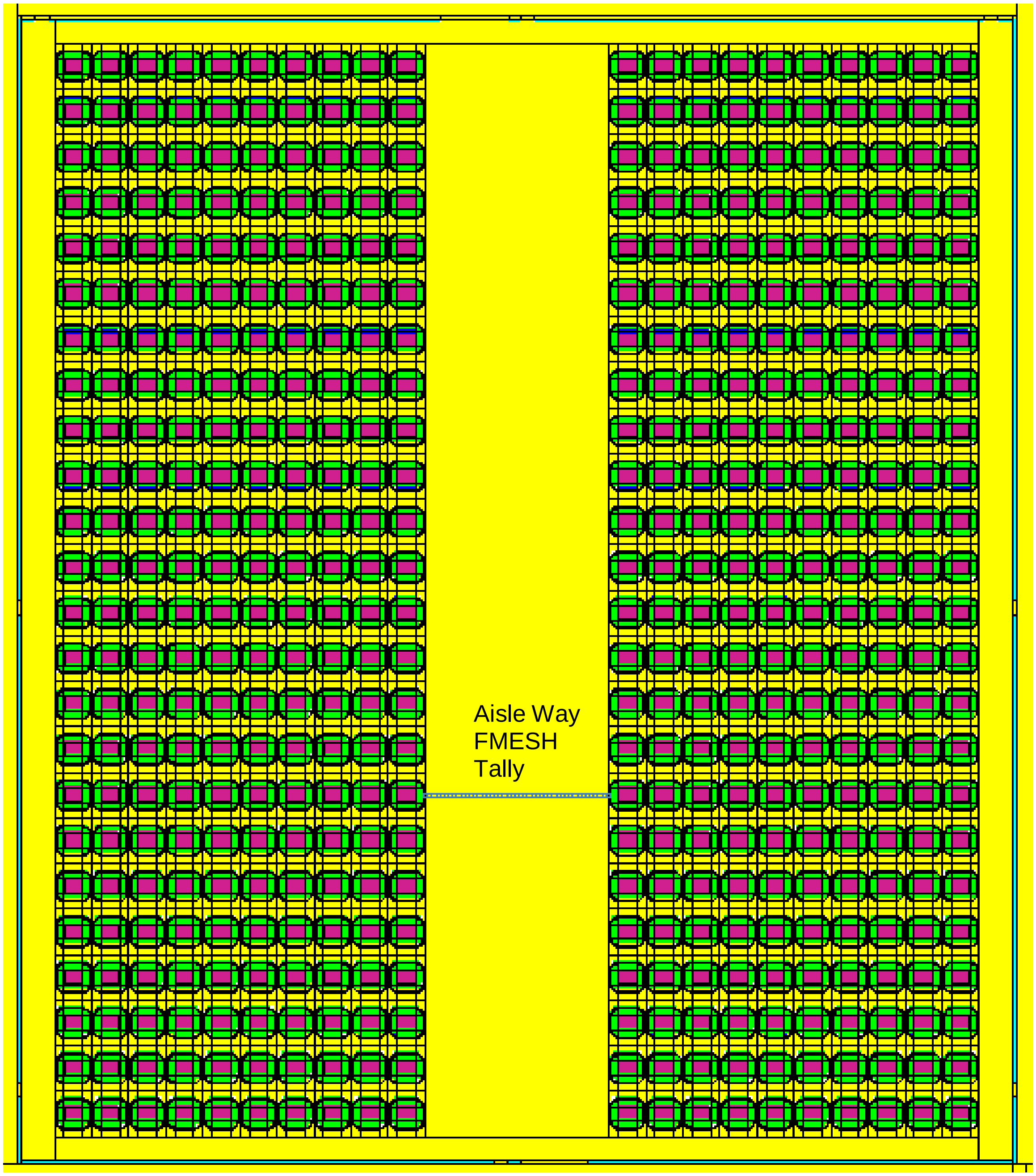

Figure 11 MCNP Representation of FMESH Tally across Aisle Way of SB3[17]

[17] The dose rate profile across the aisle way is shown in Figure 15.

Figure 12   Dose Receptor Locations

Figure 13 Sketch of Mesh Tally Locations (green) around SB3 and SB4

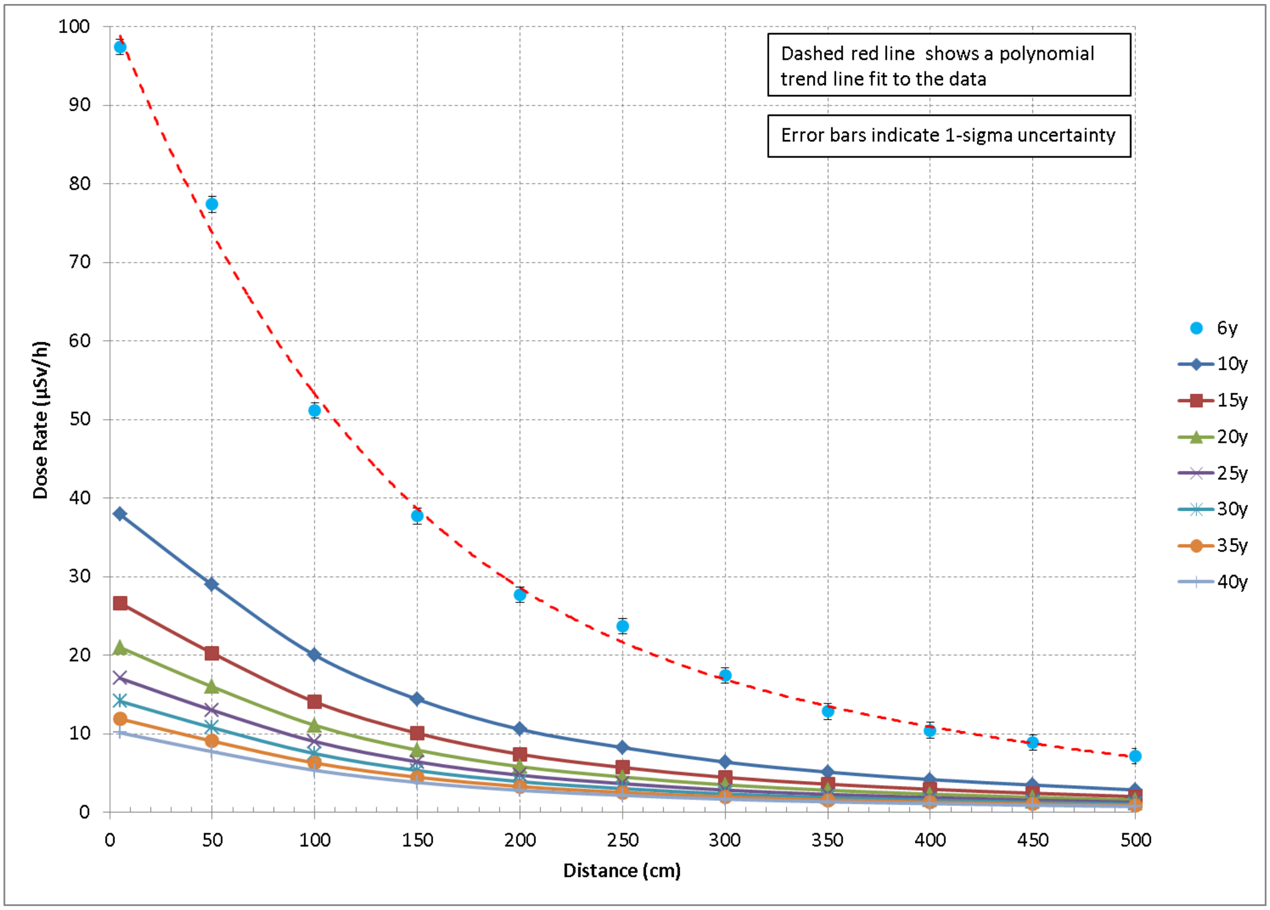

Figure 14 Calculated Dose Rate vs. Distance from the Long Side of a Single DSC at Various Fuel Decay Times

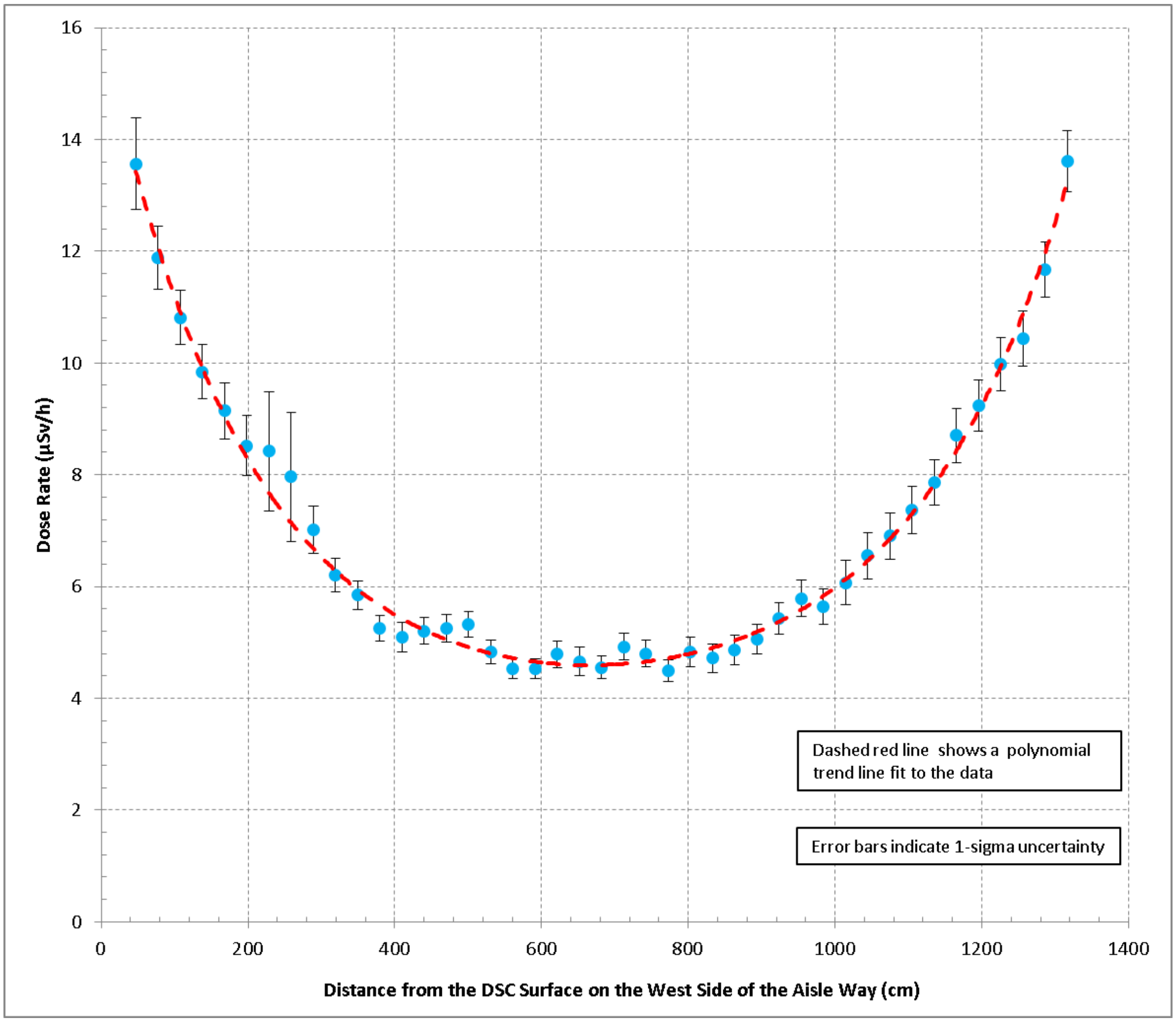

Figure 15 Dose Rate (µSv/h) Across the Main Aisle Way of SB3[18]

18 The data points at ~230 cm and ~260 cm have associated uncertainties outside the target specified in Section 3.10. These 2 points are included in the figure for presentation purposes only and are excluded from the generation of the trend line fit.

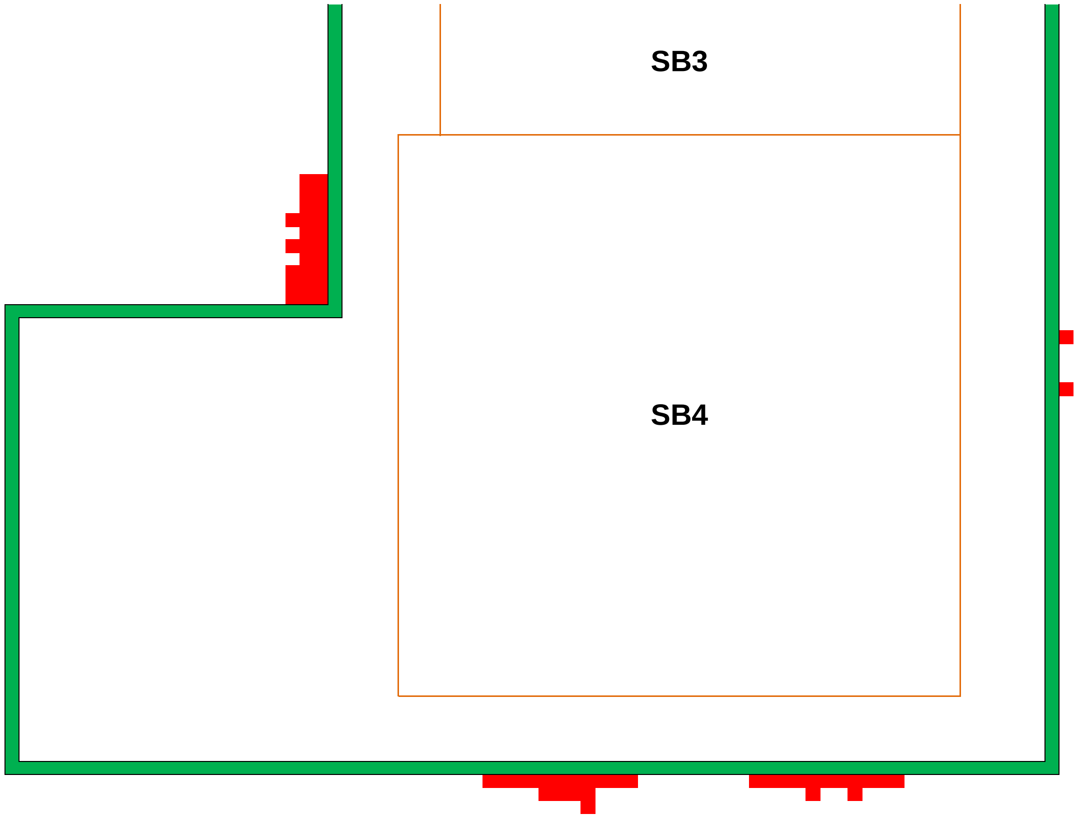

Figure 16 Representation of Dose Rates Exceeding Acceptance Criterion (red) Outside PWMF Phase II Protected Area Fence (green)[19]

[19] Dose rates (best estimate + 2σ uncertainty) are compared against the 0.5 µSv/h acceptance criterion (see Section 2). Each cell corresponds to a 2 m x 2 m x 2 m volume.

ENCLOSURE #4

OPG letter, P. Dinner to Y. Mroueh,
“Additional Information Concerning: Thermal Gradients Pertaining to Dry Storage Containers (DSCs)”
00104-CORR-79171-0139942

ONTARIOPOWER GENERATION

700 University Avenue Toronto, Ontario M5G 1X6

May 4, 2005

File#: 00104-79171 (P)

Dr. Youssef Mroueh
2120 Blue Ridge Crescent
Pickering, Ontario
L1X 2N3

Dear Dr. Mroueh:

Additional Information Concerning Thermal Gradients Pertaining to Dry Storage Containers (DSCs)

Reference: Paul Dinner, letter to Dr Youssef Mroueh, "Questions in Connection with the Dry Storage Container for Used Fuel", September 10, 2004.

This letter is a follow-up to our discussions last August and my letter of September 10, 2004. At that time we discussed, amongst other issues, the subject of heat transfer in the loaded DSC. In section (b) of my letter, I described the process of heat transfer in the DSC, the temperature monitoring program conducted in the field in 1998 on a specially instrumented DSC containing 6-year old fuel (DSC 0024), and the simulation modeling carried out for us by ANSYS using their computational fluid dynamics software. I noted in summary that temperatures, both calculated and measured, are much less than permitted by the DSC design.

00104-79171 - 0139942

Recently, I understand that you spoke with my colleague Dr. Atika Khan concerning the early work done on the Concrete Integrated Container (CIC), an experimental fuel storage container which was built and tested at Pickering during the early 1990's. You requested information from that testing program pertaining to the thermal behaviour of the CIC. I believe that you may have been given the impression that a report containing consolidated information on the dismantling of the CIC's existed. I have not been able to locate such a report (indeed, the CIC's have never been dismantled – they were unloaded, decontaminated, and put in storage at our Western Waste Management Facility. However, Dr. Khan has been able to provide me with results of the thermal measurements conducted between 1990 and 1993 (from a CIC designated as number 2). These data are plotted in Figure 1 (attached). Please note that the maximum inner liner temperature observed was about 50°C.

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The modest temperature conditions observed in the CIC containers were as expected and supported Ontario Hydro's decision to move forward with used fuel dry storage.

In order to provide you with the basis for a deeper understanding of the spatial temperature distribution in dry storage containers, I am enclosing a copy of our report on the Thermal Monitoring of Pickering DSC 0024. The data in this report provide the basis for the statements in paragraph 2 (above), discussed with you in our meeting of last August.

You will note that the temperatures from the CIC are consistent with those observed for the Dry Storage Container of the type in use today, although the DSC temperatures are nominally greater owing to the fact that DSC 0024 was situated amongst an array of other loaded DSCs in storage.

Thank you again for your interest in our Dry Storage program. We appreciate the efforts you have made to understand the key safety aspects of the DSC design.

Sincerely,

Paul Dinner
Manager, Nuclear Waste Engineering
Nuclear Waste Management Division

/attach.

cc: Frank King, H17-F20
Atika Khan, H17-B22

bcc: John Vincent
Terry Squire, H17-F26
Janice Hudson, P26 W2

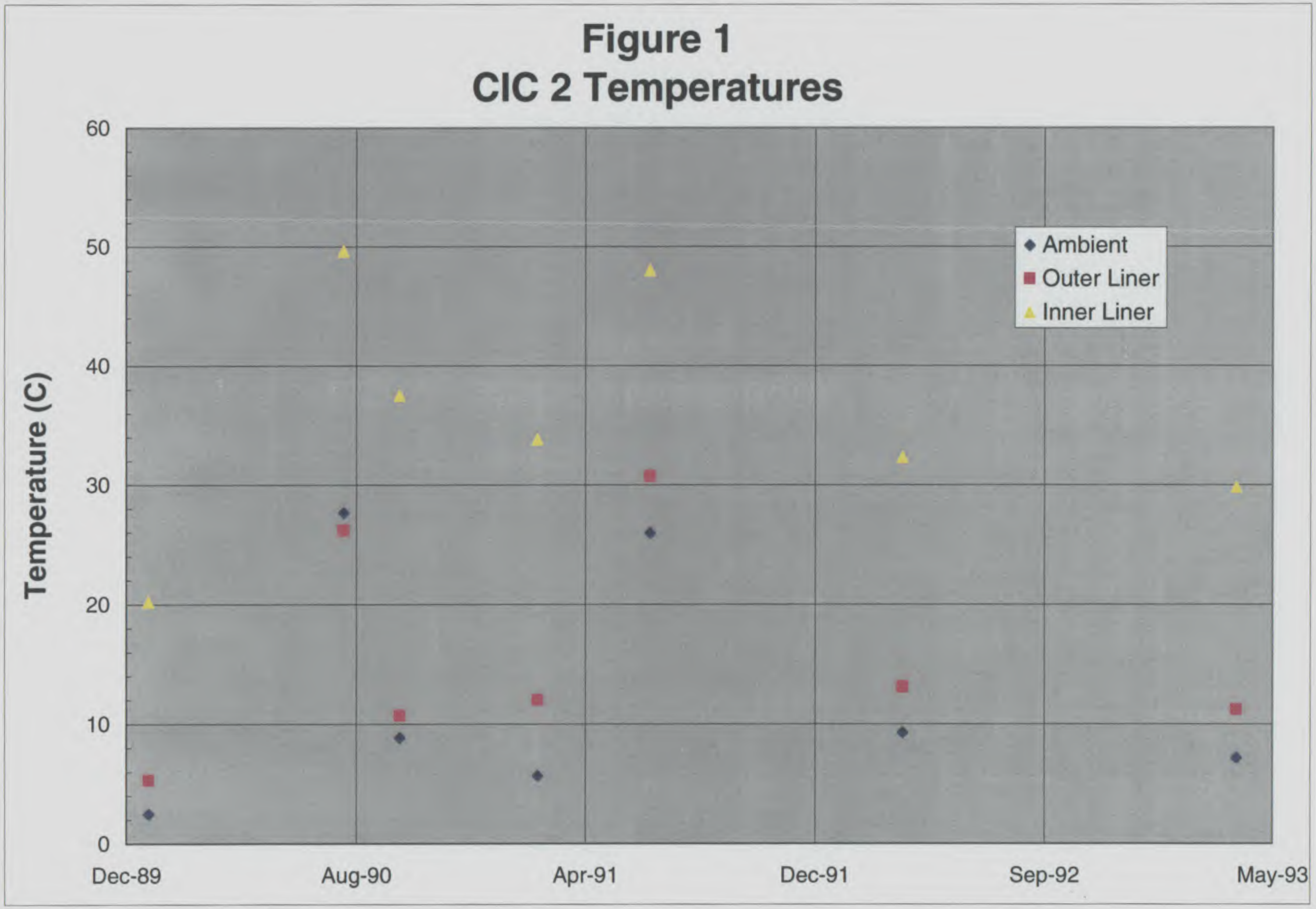
Figure 1
CIC 2 Temperatures
Temperature (C)
60
50
40
30
20
10
0
Dec-89
Aug-90
Apr-91
Dec-91
Sep-92
May-93
Ambient
Outer Liner
Inner Liner

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File:6119-1997	Revision: 0	Date: October 27, 1998

Temperature Measurements Summary Sheet

Ontario Hydro Technologies

Description: Thermal Monitoring of a Pickering Dry Storage Container (DSC) stored inside the Pickering Used Fuel Dry Storage Facility (PUFDSF) during June, July and August 1998.

Method Used: The required temperature data were obtained through a remote controlled Data Logging (DL) system. Measurements were made for a DSC instrumented with a total of 34 Thermocouples (TCs). The data were processed to produce plots of temperature histories and time-averages for all the TCs monitored. In addition, standard deviation, standard error and coefficients of variation were also calculated.

Conclusion: The average measured indoor air temperature is 26°C while the measured average outdoor ambient temperature is 22°C. That is 12°C lower than the design indoor air temperature of 38°C used for the DSC analysis. The recorded maximum temperature at the DSC's inner liner is 61°C. When this maximum inner liner temperature is corrected for the 12°C difference between the design and measured indoor air temperatures it gives a maximum inner liner temperature of 73°C. This is 21°C lower than the predicted maximum inner liner temperature of 94°C. Therefore the temperature results of the monitoring program confirm that the thermal performance of the DSC is much better than predicted.

Prepared by: D. Taralis
Title/Department: Sr. Research Engineer/ Mechanical Systems Performance/ OHT
Date: October 27, 1998

Reviewed by: B.E. Mills
Title/Department: Sr. Research Engineer/ Mechanical Systems Performance/ OHT
Date: October 27, 1998

Approved by: W.H.S. Lawson
Title/Department: Manager/ Mechanical Systems Performance/ OHT
Date: October 27, 1998

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THERMAL PERFORMANCE VERIFICATION OF PICKERING DRY STORAGE CONTAINER

1. Introduction

The thermal monitoring program of a full-scale Pickering Dry Storage Container (DSC) was developed to address AECB requirements regarding safe temperatures for used fuel during dry storage. The objective of the temperature measurements was to confirm that the thermal performance of the container stored within the Pickering Used Fuel Dry Storage Facility (PUFDSF) is not worse than predicted/1/ under the worst case scenario of 6 year old fuel and summer temperatures.

To accomplish the above objective, Pickering DSC #24 was instrumented with 24 Thermocouples (TCs) at the inner and outer surfaces of the walls. The instrumented container was loaded with 6 year cooled fuel and placed within an array of DSCs containing 10 year old fuel. A remotely controlled Data Logging (DL) System designed for this application was used to collect the required temperature data at regular intervals of time over a three-month period (June, July and August, 1998).

This report describes the instrumented DSC, the Data Logging (DL) System used to collect the data as well as the method for processing and analysing the results. Furthermore, the maximum temperatures registered on the inner liner are identified and compared with the predicted inner liner temperatures. The final conclusions reached from the monitoring program are also presented.

a) Description of Test Equipment & Monitoring System

This Section describes the main components of the equipment used for making the required temperature measurements:

- **Instrumented DSC**
- **DSC Test Array**
- **Data Logging System**

Instrumented DSC: Pickering DSC #24 was instrumented with 24 TCs during its construction phase. The specifications for the TCs used and their locations are described below. All TCs were tested before and after installation to ensure proper operation.

Thermocouple Specifications: The temperature measurements were made using type K TCs which conform to QA standards of ANSI M96.1-1992 and ASTM E230-1993. The TC wire size used was 30 AWG. An inconel outer sheath of 1.5 mm (1/16") diameter contained the TC wires which were embedded in compressed magnesium dioxide powder insulation. The length of the TCs varied, depending on the location of their junction, and were sized to within 0.5 m of the actual routed length. The TCs leads were terminated with integral miniature female connectors to facilitate connections to the DL system.

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Thermocouple Locations: Figures 1 and 2 show the location of the TC junctions where the temperature measurements were made. These TCs were grouped (for installation purposes) as follows:

a. Fourteen TCs on the outer surface of the inner liner

b. One TC at the outer surface of the outer liner (bottom)

c. Nine TCs at the inner surface of the outer liner

d. Six TCs in the air spaces between the instrumented DSC and the surrounding DSCs

   These TCs were installed on two adjacent vertical sides of the instrumented DSC at three elevations and were attached to the DSC outer surfaces using magnetic mounting. The TCs extend out horizontally from the vertical surfaces (0.1 m from one side and 0.3 m from the other).

e. One TC above the DSC top (0.1 m away from the top surface)

f. Three TCs for ambient air (2 TCs for air within the Dry Storage Facility (DSF) and 1 TC for outdoor air)

A total of 34 TCs (24 on DSC and 10 for air) were used to make the temperature measurements. For redundancy purposes there were two locations on the DSC lid (inner and outer liners) which were instrumented with 3 TCs at each location.

Thermocouple Installation: The installation of the TCs was carried out by co-ordinating the fabrication schedule of the DSC with the installation procedure of the instrumentation (actual installation of TCs was carried out by OHT personnel with the assistance of the DSC manufacturer/2/). To interface with the normal production process all the required information and drawings were provided to the manufacturer well in advance. Any changes considered necessary were made to the standard DSC produotion procedure with hold points to facilitate the installation of the instrumentation. Further details are available in Reference/3/.

DSC Test Array: The thermal performance verification test was carried out within the PUFDSF. The instrumented DSC was fully loaded with 384 fuel bundles of approximately 6 year old (estimated decay heat of 7.4 W/Bundle) and stored within the facility in a test array as shown in Figure 3. The DSCs in the immediate vicinity of the instrumented container were loaded with 10 year used fuel as defined in the test plan submitted to the AECB/1/. When the required number of loaded DSCs were in place, the monitoring program began.

Data Logging System: The temperature data were collected using a Campbell Scientific portable Data Logging (DL) System (Model 21X). This system (see Figure 4) is capable of accepting up to 64 TCs or other voltage inputs. It can store up to several days of data (based on half-hour interval scanning) before it becomes necessary to download the data to the controlling PC. The DL System was located in a nearby location within the PUFDSF (see Figure 2) and connected to the TCs by a standard thermocouple extension cable which is normally used for such applications. The DL System was calibrated prior to the collection of temperature data and also at the end of the monitoring period. Based on this calibration the accuracy of all the temperature measurements made was within ± 2.2 °C (standard error of type K TCs is 2.2 °C or ± 0.75% whichever is greater in the temperature range of 0 to 1250 °C).

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To control the monitoring of the instrumented DSC remotely, a telephone/modem connection was made to the data logger at the Remote Site and to a PC at the receiving end. This enabled real-time monitoring and data collection from the OHT site (800 Kipling Ave., Toronto) and minimized the requirements for frequent site visits.

The monitoring program conducted covered a period of three months. Since the main purpose of the study was to collect data that represent the maximum possible temperatures, the program was carried out during the hottest months of the year (i.e. June through August). The results of this study are presented below:

b) Presentation of Temperature Measurements

To facilitate the presentation of the field measurements, the temperature data obtained from all the TCs have been grouped as follows:

Air & Air Spaces

- Outdoor ambient air temperature and its arithmetic and time-averages (Figure 5)
- Indoor air temperature (Figure 6)
- Air temperature between two DSC vertical sides and surrounding DSCs including top of DSC (Figure 7)

Outer Liner:

- Two adjacent vertical sides (Figure 8)
- Top and bottom (Figure 9)

Inner Liner

- Two adjacent vertical sides (Figure 10)
- Top and bottom (Figure 11)

The maximum temperatures obtained over the entire monitoring period at locations of interest are presented in Table 1. The corresponding temperature distribution throughout the container is illustrated in Figure 12.

The maximum temperature measured (61°C) occurred on July 24, 1998 (about 45 days after the monitoring program began). This temperature corresponds to TC location #4 (which is located near the top of the inner liner approximately 1.89m from the bottom of the cavity as shown in Figure 1).

In addition to the above results, the time-average of all the TCs including the ambient outdoor temperature and standard deviation have been calculated. The equations used for obtaining the statistical quantities are presented in Table 2 and the results obtained in Table 3. These results have been processed further to produce the average values shown in Table 4 for the TC groups presented above.

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c) **Analysis and Assessment of Temperature Measurements**

This Section describes the analysis of the temperature measurements including the assessment of conditions under which the measurements were made.

Temperature difference across the walls: An examination of the inner and outer liner temperatures (see Table 3 for TC#4 & TC#20) reveals a maximum temperature difference of the order of 20 °C, occurring across the DSC vertical wall adjacent to the drain and vent side. This is to be expected, since this side and opposite side are closer to the surrounding DSCs. The minimum difference occurs across the bottom wall (approximately 7 °C). This smaller temperature difference indicates that the heat transfer rate to the floor is not as high.

Variation of wall temperatures with DSC height: Further examination of the results obtained (see Figure 12 reveals that the inner liner temperature increases with the vertical distance from the bottom of the DSC cavity until a height of 1.89 m is reached (location of maximum temperature of 61 °C). Beyond this height the vertical wall temperatures begin to fall. This observation is consistent with previous analytical results presented in the Pickering Safety Report (SR)/1/.

Correlation of Outdoor versus Indoor Air Temperatures: Figure 13 shows the outdoor (TC#34) and indoor (TC#33) air temperatures as well as the outer (TC#20) and inner (TC#4) liner temperatures. As this figure reveals, a given fluctuation in outdoor ambient temperature is followed by a much smaller fluctuation in the indoor air temperature with a slight delay. The outer surface temperature fluctuations due to the DSC thermal inertia are even smaller. Furthermore, the maximum inner liner temperature is rather insensitive to these outdoor air temperature fluctuations. Although the highest outdoor temperature recorded occurred much later (August 11/98), the maximum inner liner temperature did not increase any further. In fact this maximum temperature began to decline, reaching 58 °C at the end of the monitoring period (September 9, 1998). It appears that due to the large thermal inertia of the container the DSC temperatures are only a function of the time-average of the outdoor ambient temperature.

Assessment of Conditions During Measurements: The above results are assessed with respect to the following parameters:

a. Test array containing a DSC loaded with 6 year old fuel at the centre of the array
b. Hottest weather conditions with daily temperature variation versus DSC analysis carried out using constant indoor air temperature of 38°C
c. Facility being less than full capacity at time of measurements
d. Covered ventilation louvres versus openings for ventilation in the analysis
e. Time between loading and beginning of measurements

Effects of Fuel Age: The fuel stored within the DSCs will be much older than 6 years (minimum 10 year old; 15 years old on the average). The corresponding decay heat of the fuel will be lower and consequently the DSC temperatures are expected to be lower.

Effects of Lower Ambient Conditions: As Figure 5 and Table 1 (TC#34) indicate, the maximum outdoor air temperature during the entire 3-month monitoring period reached 38.6 °C for a short instant of time (occurred August 11/98 at 3:30 pm). The time-average of the ambient air temperature experienced during the monitoring period was determined to be about 22°C (see Figure 5 and Table 3). The difference between the time-average of the indoor air temperature (26°C) and

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the temperature used in the DSC analysis/1/ (38 °C) is 12°C. A previous study /4/ indicated, a nearly linear relationship between ambient air temperature and DSC temperatures. Therefore, adding the 12°C difference to the actual maximum inner liner temperature of 61°C results in 73°C. This is 21°C below the predicted maximum inner liner temperature of 94°C.

The difference between measurements and predictions can be attributed to the various conservative assumptions made in the analysis, such as DSC being in non-black environment (zero radiant heat loss from the DSC outer surface) and conservative decay heat value.

Effects of Closed Ventilation Louvres: During the entire monitoring period the facility's ventilation louvres remained closed. The effect of this would be to restrict the indoor warm air from exiting the facility. If the louvres were kept open, the indoor air as well as DSC temperatures would have been somewhat lower than the present measured values.

Effects of Partially Filled Facility: Since the facility was not near full capacity (about 33% occupied with loaded DSCs and about 20% with empty DSCs) at the time of measurements, the temperatures for a full facility would be expected to be somewhat higher during the hottest season. This is because the difference between the indoor and outdoor average temperatures is only 4°C for the presently 1/3 filled facility. Assuming the decay heat of the fuel remains constant, when the facility becomes 100% full with loaded DSCs, the maximum additional increase in facility and DSC temperatures would be expected to be 8°C (assuming 4°C for each additional one third of facility being filled). However, even if such an increase occurred, the maximum inner liner temperature would still be lower by 13°C (21°C - 8°C) than the predicted maximum of 94°C.

Based on the present results and the fact that the decay heat of the fuel decreases with age, it seems very unlikely that the DSC temperatures will increase appreciably (as the facility becomes full) in subsequent years.

Effects of DSC Thermal Inertia: Although the DSC has large thermal inertia due to its mass, it takes of the order of two weeks for the container to reach steady-state conditions /4,5/ following a given change in outdoor ambient air temperature. Therefore, since the monitoring period of 3 months is considered sufficiently long for the DSC to reach thermal equilibrium within the facility, it follows that the maximum DSC temperatures were reached during this test period.

Effects of Time Between Loading & Measurements: The elapsed time between the loading of the DSC with 6 year old fuel and the time the DSC was placed in the facility (within the test array) was relatively long (about two weeks). Therefore, at the time of measurements the DSC was close to thermal equilibrium with a maximum inner liner temperature of about 57 °C (see Figure 10). As the monitoring results indicate at the beginning of measurements (about 10 to 15 days after loading the container) the DSC temperatures were decreasing as a result of the lower outdoor temperature (see Figure 5).

d) Conclusions

Based on the analysis of the temperature data obtained from the thermal monitoring of the Pickering DSC loaded with 6 year old fuel the following conclusions can be made:

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a. The time-averaged air temperature within the facility during summer was 26°C. The corresponding time-averaged outdoor ambient temperature was 22°C. The inner wall temperature reached a maximum value of 61 °C. This temperature (when adjusted by 12°C to account for the difference between the design indoor ambient air temperature of 38°C and the measured value of 26°C) is 73°C, which is still 21°C below the predicted value of 94°C.

b. The effect of the facility not being full at the time of DSC temperature measurements was estimated to be of the order of 8°C higher. Accounting for this effect, the DSC inner liner maximum temperature is still expected to remain below the predicted maximum of 94°C (about 13°C lower).

c. Using the measured maximum inner liner temperature (adjusted for the difference in the indoor air temperatures between measurements and analysis) the fuel sheath temperature is expected to be lower by about 21°C than the previously predicted value of 173°C (i.e.152°C).

In the long term, as the fuel ages, the heat load of the containers will gradually fall resulting in lower fuel sheath and DSC wall temperatures, thus further reducing the likelihood of any temperature-related degradation of the fuel and the container.

References

1. Pickering Used Fuel Dry Storage Facility, Safety Report, File 907-92896-00531-P, January 21, 1994.

2. Taylor Forge Ltd., Niagara Falls, Ontario, Canada (DSC Manufacturer).

3. Mills, B.E. and Taralis, D., "Dry Storage Container Thermal Performance Verification Test Plan", OHT Document, File: 825.122, October 24, 1995.

4. Bruce Used Fuel Dry Storage Facility Safety Report, A Report to the Atomic Energy Control Board, 1997.

5. Taralis, D., Mills, B. E. and Shah, N. N., "Thermal Testing of a Concrete Integrated Container (CIC) for the Ukraine Dry Storage Program: Phase I", Ontario Hydro Technologies, Report No. A-NBP-96-84-CON.

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TABLE 1
MEASUREMENTS OF MAXIMUM TEMPERATURES

Description/Location[1]	Temperature, °C
Inner Liner	
•Adjacent to Drain & Vent Side	60.9
•Opposite to Drain & Vent Side	52.5
Outer liner	
•Adjacent to Drain & Vent Side	42.3
•Opposite to Drain & Vent Side	41.9
Air Space	34.6
Indoor Ambient	33.7
Outdoor Ambient	38.6

(1) For Location See Figures 1 & 2

TABLE 2
EQUATIONS FOR CALCULATING STATISTICAL QUANTITIES FROM TEMPERATURE MEASUREMENTS

Statistical Quantity	Equation
Time-Average, °C	$\overline{T_{ji}} = \{ T_{j1}\,\Delta t_1 + T_{j2}\,\Delta t_2 + \bullet\bullet\bullet + T_{jn}\,\Delta t_n \}/t$
Arithmetic Average, °C	$T^{*}_{j} = 1/n \sum_{i=1}^{n} T_{ji}$
Standard Deviation, °C	$\sigma_j = \{ 1/n \sum_{i=1}^{n} (T_{ji} - \overline{T_j})^2 \}^{1/2}$
Standard Deviation of the Mean, °C (Standard Error)	$\varepsilon_j = \sigma_j / n^{1/2}$
Coefficient of Variation	$C_j = \sigma_j / \overline{T_j}$

j=1 to 34 (number of channels)
i = 1 to n (number of time steps/sampling points)
t = time, hours (measured from beginning of monitoring period)

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TABLE 3
SUMMARY OF TEMPERATURE MEASUREMENTS

TC #	Maximum Temperature (°C)	Time[1] of Occurrence of Maximum Temperature (Days)	Minimum Temperature (°C)	Time[1] of Occurrence Of Minimum Temperature (Days)	Mean[2] Temperature (°C)	Standard Deviation	Standard Error	Coefficient of variation
1	44.3	82.38	35.9	4.17	42.30	2.20	0.03	0.05
2	54.3	80.02	45.9	4.27	52.38	2.10	0.03	0.04
3	59.7	44.69	51.2	4.25	57.69	2.02	0.03	0.03
4	60.9	44.69	52.3	4.02	58.88	1.97	0.03	0.03
5	50.5	43.67	41.4	3.14	48.40	1.97	0.03	0.04
6	42.6	80.21	34.0	3.69	40.55	2.19	0.03	0.05
7	48.6	80.21	40.0	3.69	46.69	2.11	0.03	0.05
8	52.2	44.77	43.6	4.23	50.22	2.04	0.03	0.04
9	52.5	44.64	43.7	3.38	50.49	2.00	0.03	0.04
10	48.1	43.69	39.1	3.17	46.04	1.97	0.03	0.04
11	43.3	79.98	34.8	4.69	41.12	2.28	0.03	0.06
12	56.0	44.52	47.3	3.17	53.98	1.89	0.03	0.03
13	55.9	44.56	47.3	3.19	53.94	1.89	0.03	0.03
14	56.0	44.56	47.4	3.19	54.03	1.89	0.03	0.03
15	37.0	81.61	28.6	4.27	34.73	2.33	0.04	0.07
16	39.5	43.14	27.7	2.69	36.25	2.09	0.03	0.06
17	39.4	69.21	27.7	2.67	36.24	2.07	0.03	0.06
18	39.4	43.17	27.6	2.67	36.22	2.09	0.03	0.06
19	38.1	79.29	28.8	2.71	35.89	2.13	0.03	0.06
20	41.9	78.19	31.8	2.67	39.53	2.05	0.03	0.05
21	42.3	43.27	31.9	2.79	39.93	2.07	0.03	0.05
22	37.1	79.23	27.3	2.71	34.84	2.23	0.03	0.06
23	41.7	43.11	31.8	2.71	39.33	2.09	0.03	0.05
24	41.9	43.33	32.1	2.88	39.69	2.10	0.03	0.05
25	30.9	69.17	16.1	2.64	26.44	2.42	0.04	0.09
26	32.6	76.17	16.5	2.64	27.40	2.56	0.04	0.09
27	33.5	69.19	16.9	2.67	28.41	2.67	0.04	0.09
28	31.0	76.19	16.2	2.64	26.42	2.41	0.04	0.09
29	32.7	76.14	16.8	2.67	27.30	2.53	0.04	0.09
30	34.6	76.19	18.0	0.96	29.66	2.52	0.04	0.08
31	33.8	76.17	17.0	2.67	28.45	2.69	0.04	0.09
32	33.7	76.19	17.4	2.64	28.74	2.62	0.04	0.09
33	29.8	76.19	17.0	2.67	26.35	2.20	0.03	0.08
34	38.6	63.02	11.4	1.04	21.90	3.93	0.06	0.18

Notes:

(1) Time in days is measured from the beginning of the monitoring period (June 9, 1998)
(2) Time-Average over the entire monitoring period (see Figure 5 for comparison with arithmetic average)
(3) End of monitoring period = September 9, 1998

TABLE 4
DSC WALL AND AIR SPACE AVERAGE TEMPERATURES
(BASED ON TIME-AVERAGED VALUES)

Description	Temperatures, °C
Ambient Air:	
Indoor Air (Near DSC)	28.7
Indoor Air (Near DL System)	26.3
Outdoor Air	21.9
Air Spaces:	
Vertical Wall (Adjacent to Drain & Vent)	27.4
Vertical Wall (Opposite to Drain & Vent)	27.8
Top	28.4
Outer Liner:	
Vertical Wall (Adjacent to Drain & Vent)	38.4
Vertical Wall (Opposite to Drain & Vent)	37.9
Top	36.2
Bottom	34.7
Inner Liner:	
Vertical Wall (Adjacent to Drain & Vent)	51.9
Vertical Wall (Opposite to Drain & Vent)	46.8
Top	54.0
Bottom	41.1

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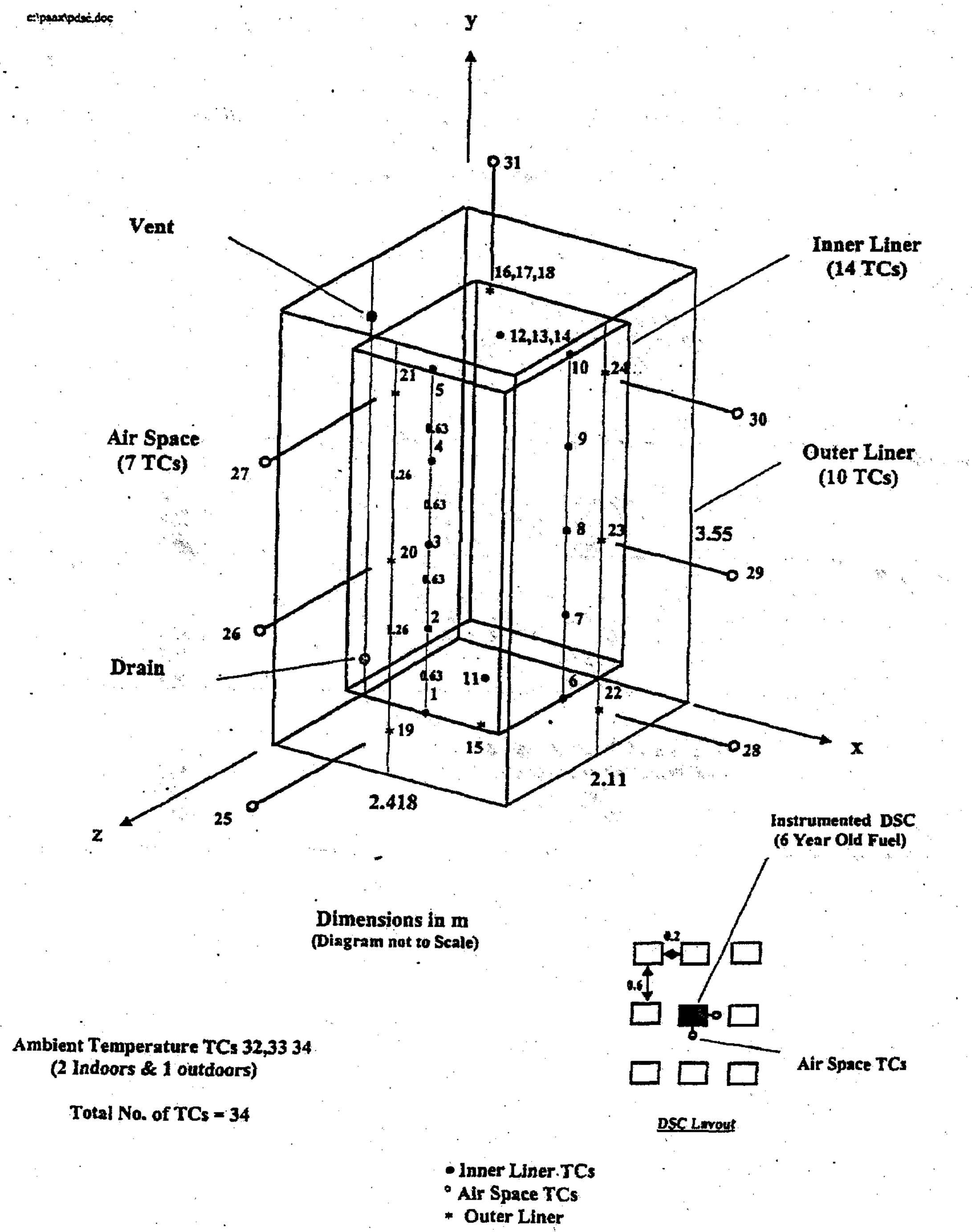


FIGURE 1
INSTRUMENTED PDSC
(THERMOCOUPLE LOCATIONS AND NUMBERING SCHEME)

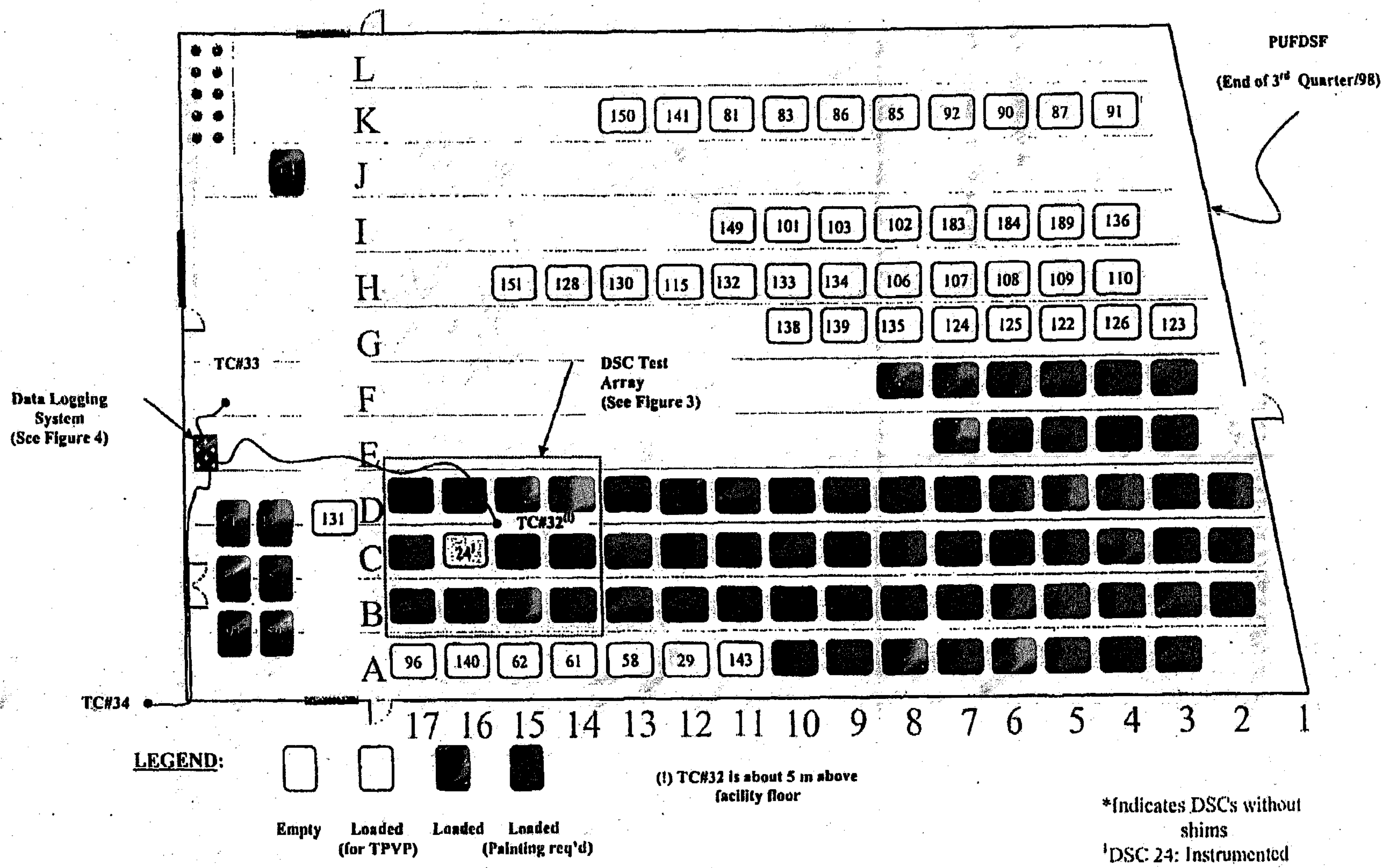
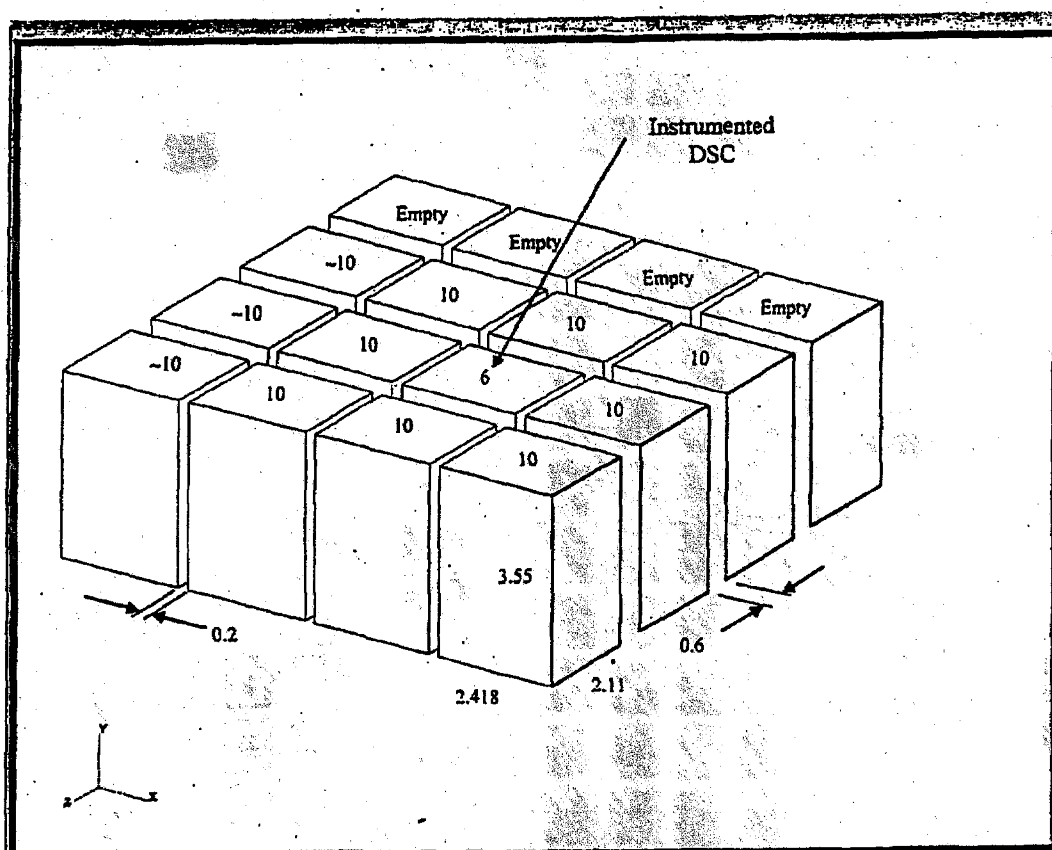


FIGURE 2
LOCATIONS OF INDOOR AND OUTDOOR AMBIENT TEMPERATURE MEASUREMENTS



Note: Numbers on the Top Plane Indicate Age of Fuel

Dimensions in m

FIGURE 3
DSC TEST ARRAY WITHIN THE PUFDSF

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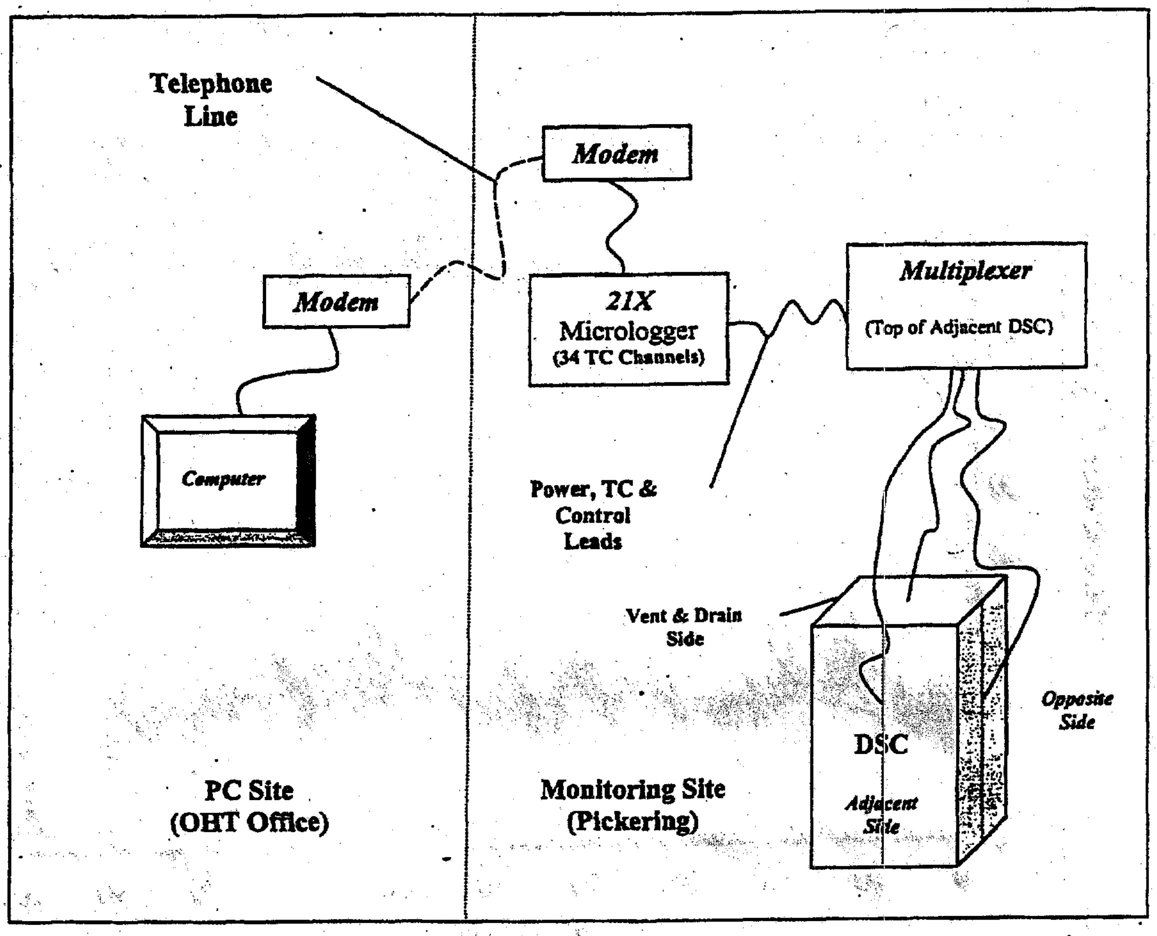

FIGURE 4
REMOTELY CONTROLLED DATA LOGGING SYSTEM

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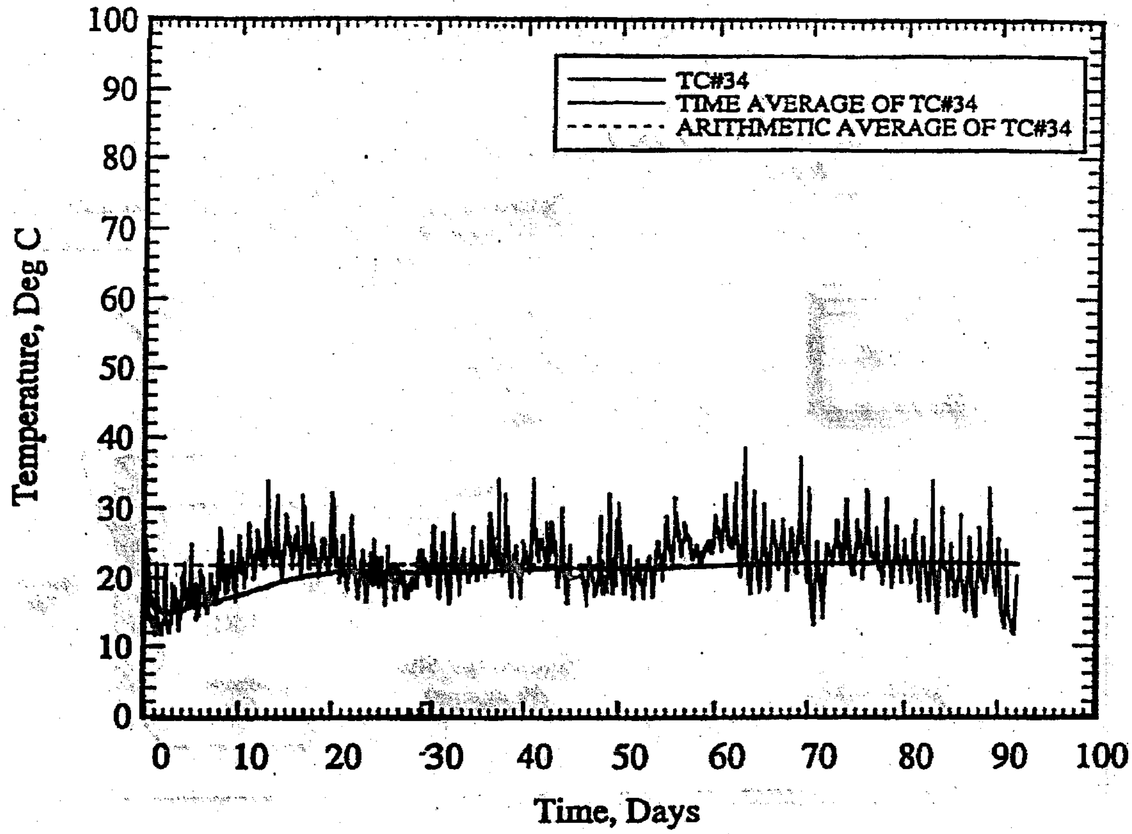
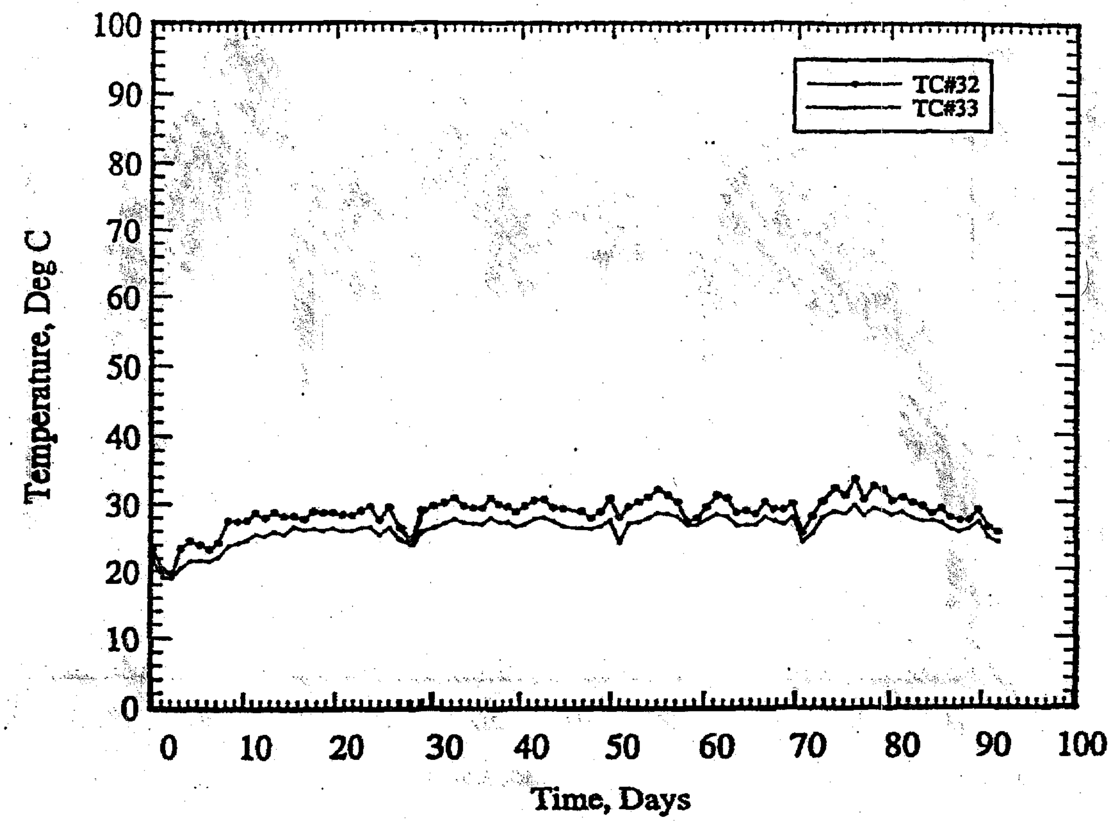


FIGUE 5
OUTDOOR TEMPERATURE HISTORY



FIGUE 6
INDOOR AIR TEMPERATURE HISTORIES

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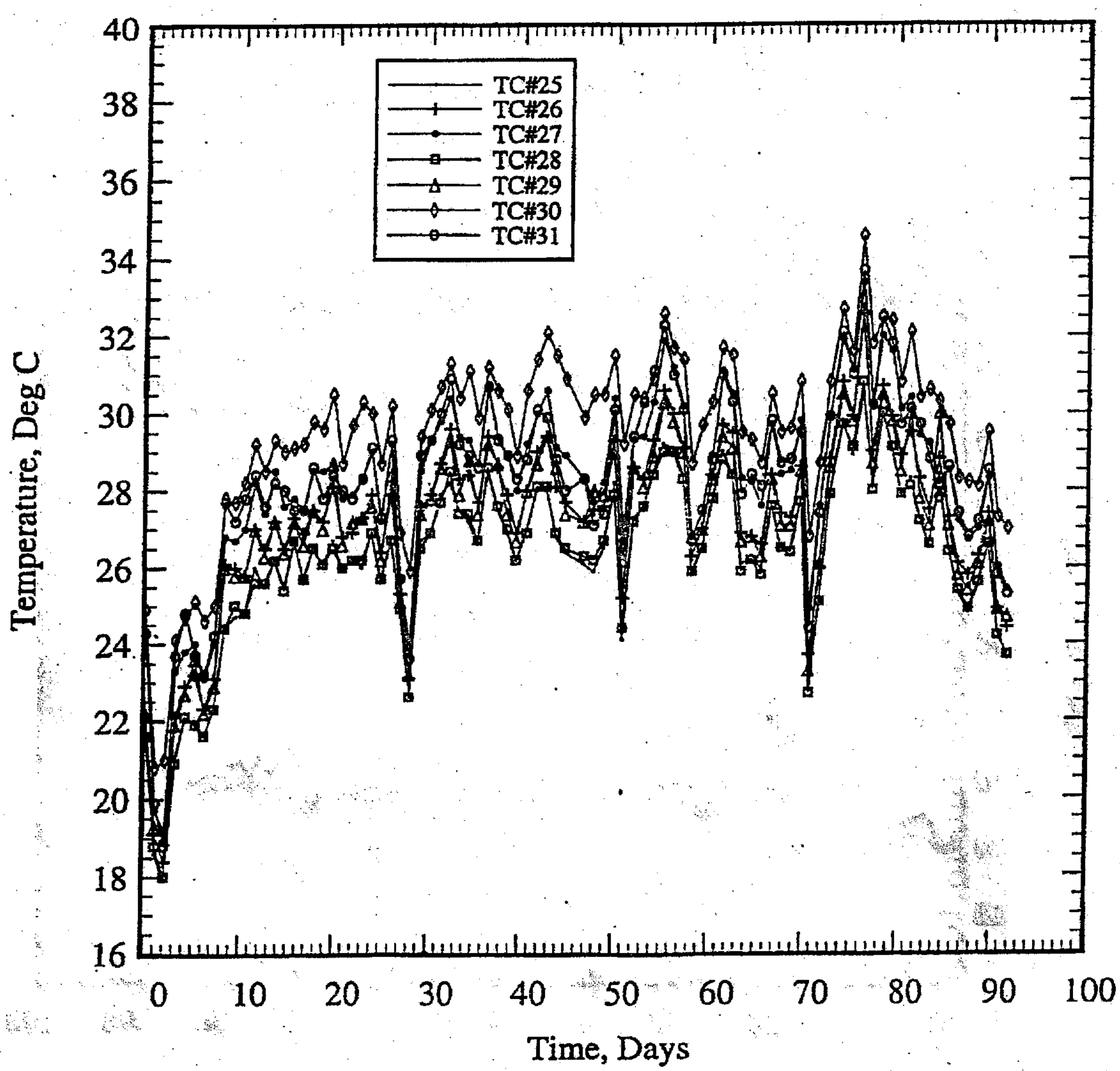
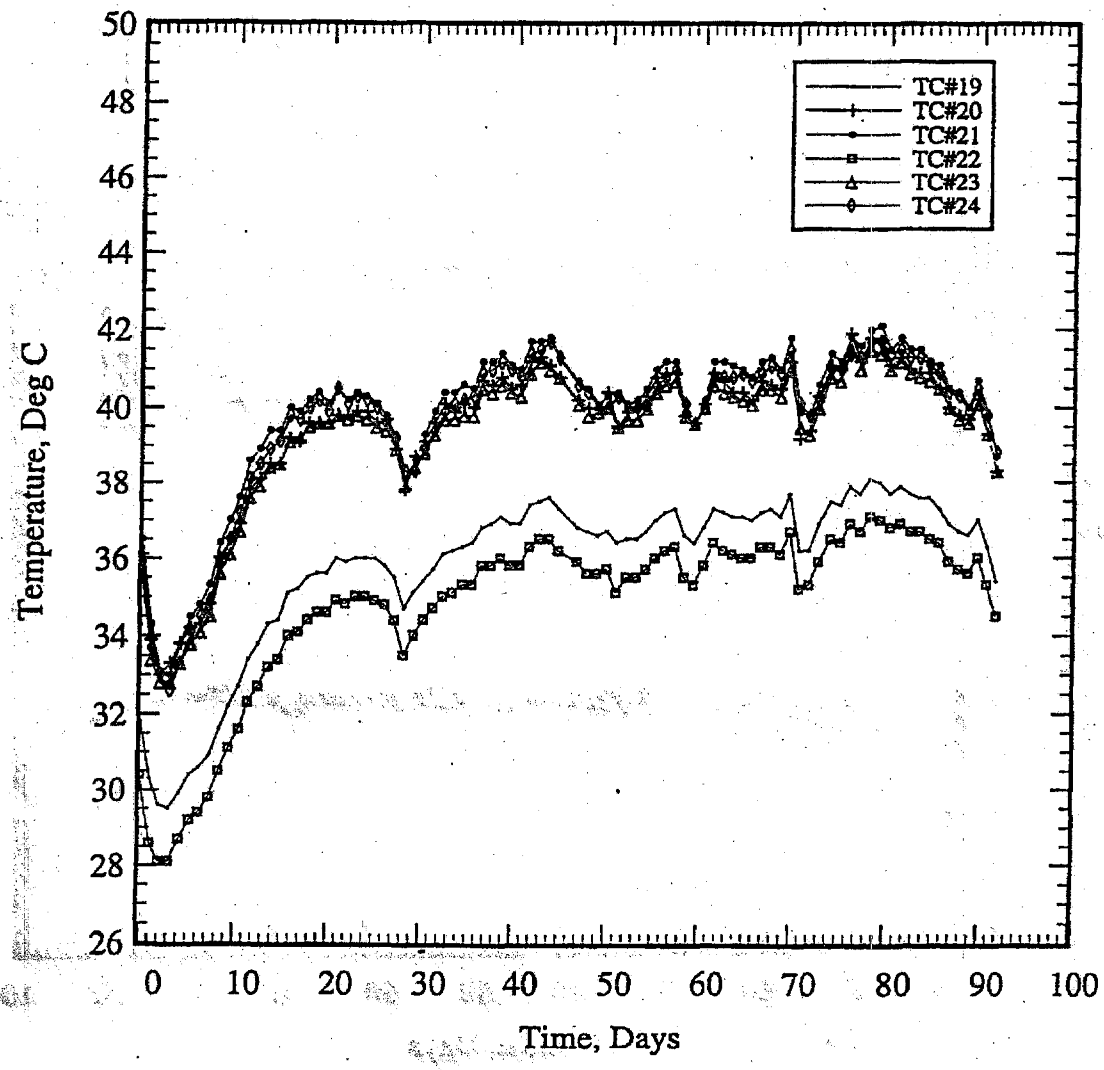
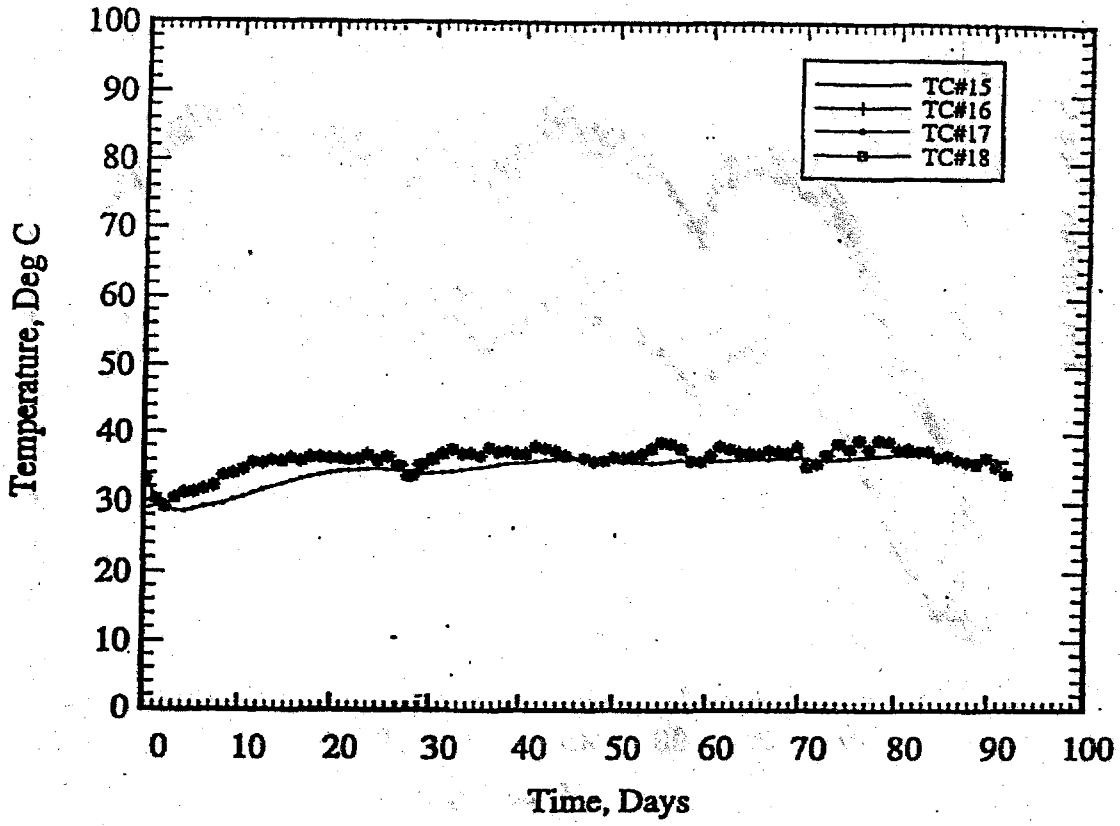


FIGUE 7
AIR SPACE TEMPERATURE HISTORIES
(VERTICAL SIDES & TOP)



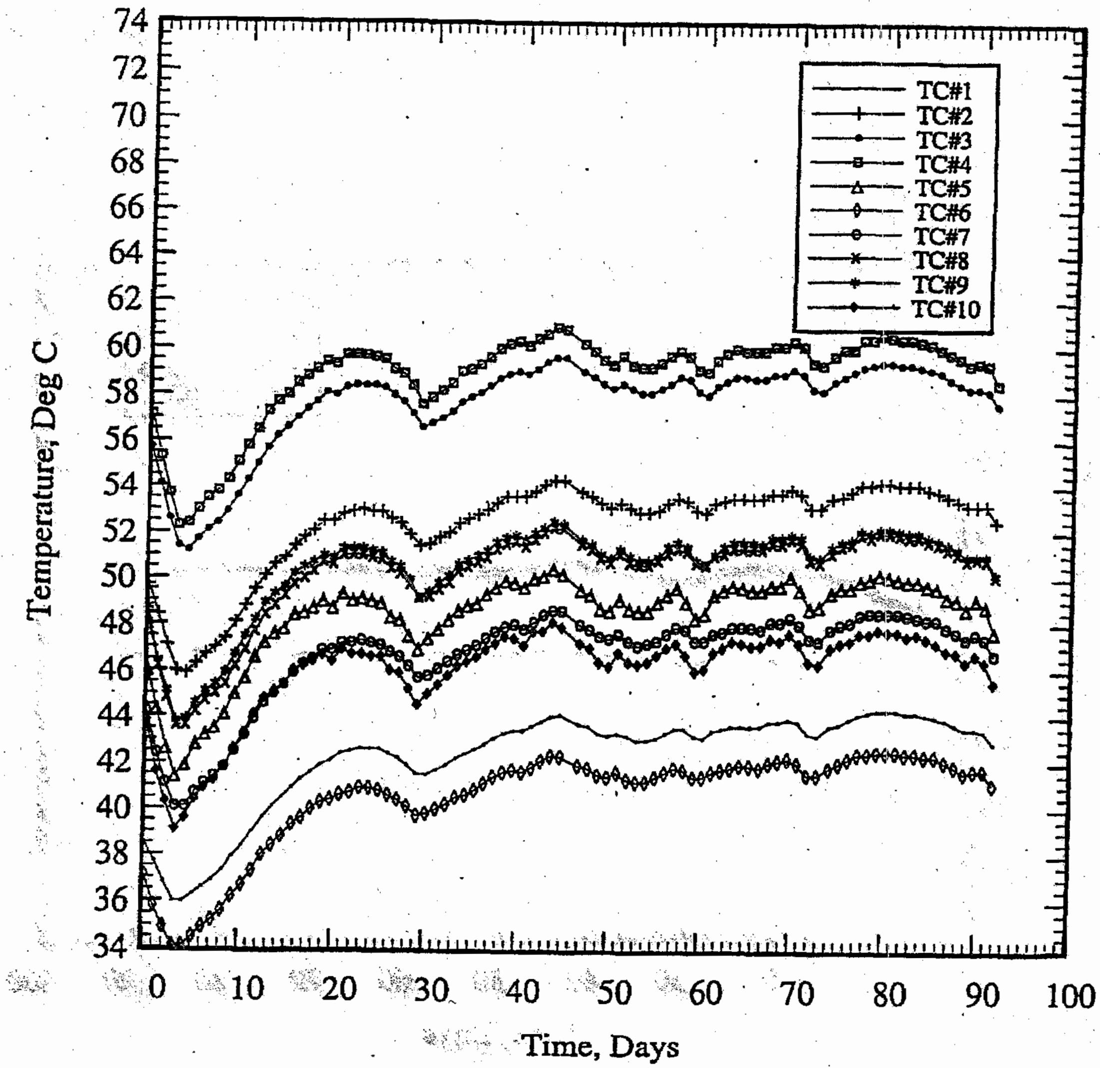
FIGUE 8
OUTER LINER TEMPERATURE HISTORIES
(VERTICAL SIDES)

Approved for Issue - VERIFY STATUS PRIOR TO USE

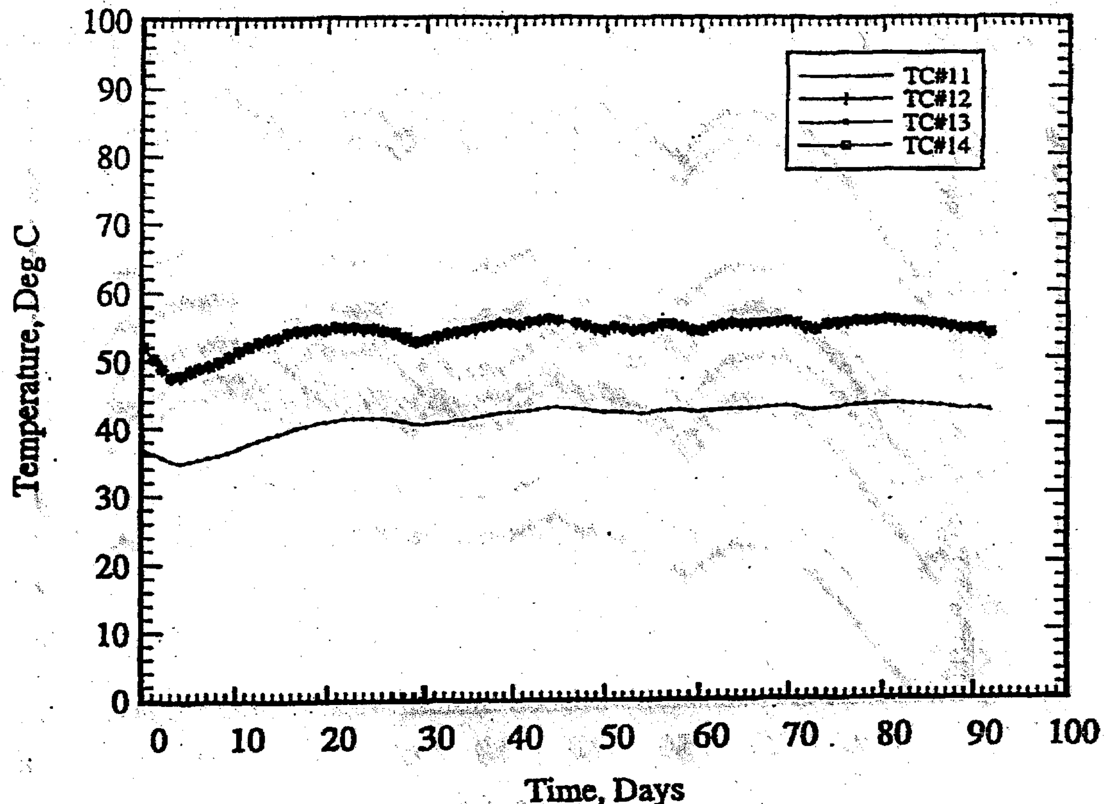


FIGUE 9
OUTER LINER TEMPERATURE HISTORIES
(TOP & BOTTOM)

Approved for Issue - VERIFY STATUS PRIOR TO USE



FIGUE 10
INNER LINER TEMPERATURE HISTORIES
(VERTICAL SIDES)



FIGUE 11
INNER LINER TEMPERATURE HISTORIES
(TOP & BOTTOM)

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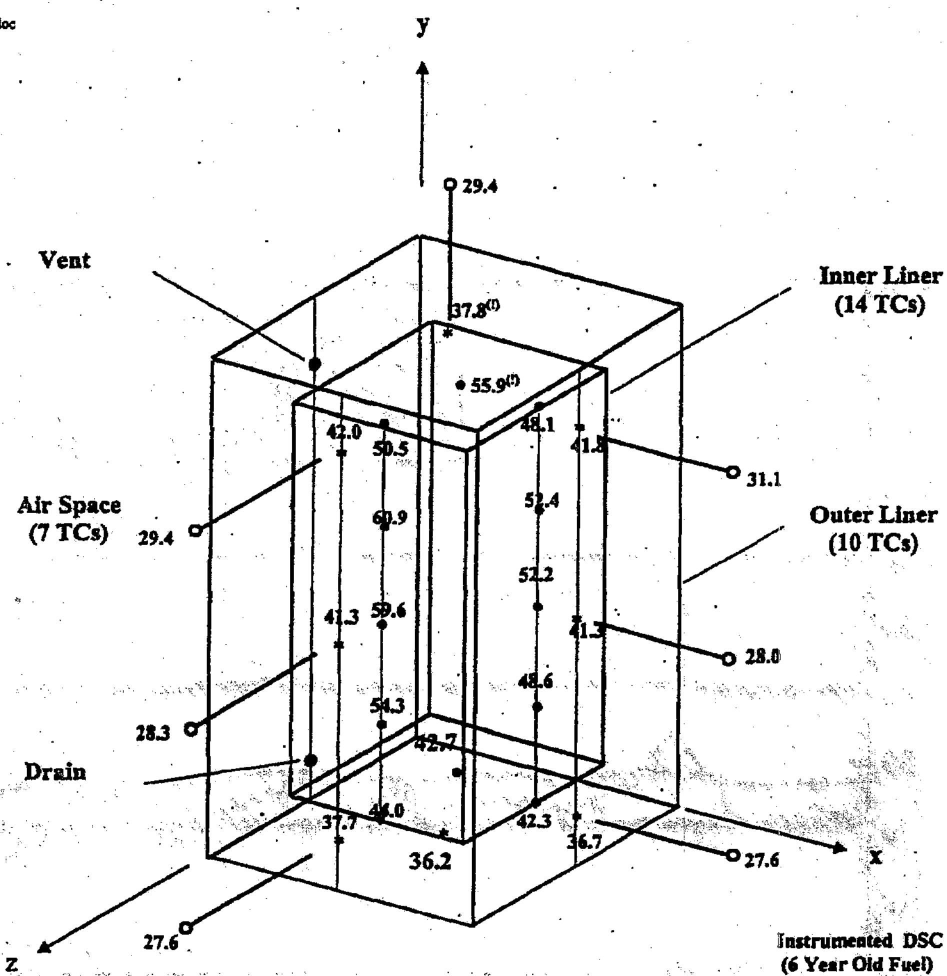
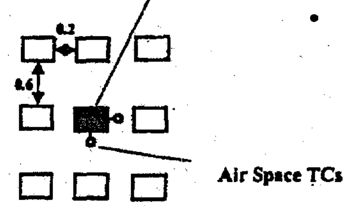


Instrumented DSC
(6 Year Old Fuel)

Dimensions in m
(Diagram not to Scale)



DSC Layout

Ambient Temperature TCs 30.2,28.0,19.6
(2 Indoors & 1 outdoors)

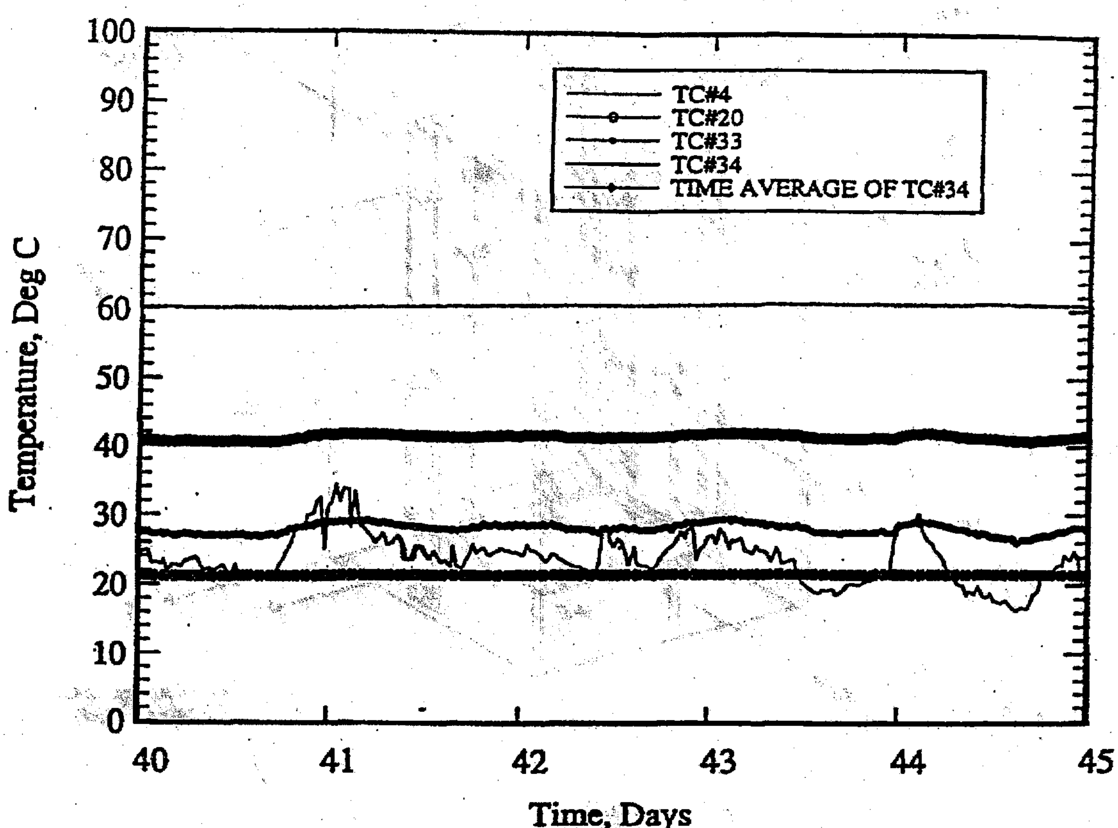
Total No. of TCs = 34

(!) Average value of 3 TCs

- • Inner Liner TCs
- ° Air Space TCs
- * Outer Liner

FIGURE 12
TEMPERATURE DISTRUBUTION AT TIME OF MAXIMUM INNER LINER TEMPERATURE
(JULY 24, 1998)

Approved for Issue - VERIFY STATUS PRIOR TO USE



FIGUE 13
CORRELATION OF INDOOR AIR AND DSC TEMPERATURES WITH OUTDOOR AIR TEMPERATURE

ONTARIO POWER GENERATION

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December 22, 2023

CD# 92896-CORR-00531-01530 P

Ms. Malaika Bacon-Dussault
Acting Commission Registrar,
Canadian Nuclear Safety Commission
P.O. Box 1046
280 Slater Street
Ottawa, Ontario, K1P 5S9

Dear Ms. Bacon-Dussault:

OPG - Addendum to the Application for Amendment to the Pickering Waste Management Facility, Waste Facility Operating Licence WFOL-W4-350.00/2028

The purpose of this letter is to submit to the Canadian Nuclear Safety Commission, referred to as "the Commission", an addendum to the application for and amendment to the Pickering Waste Management Facility (PWMF), Waste Facility Operating Licence (WFOL) WFOL-W4-350.00/2028, to be able to store minimum 6-year cooled fuel from Pickering NGS.

OPG's request for an amendment to the PWMF WFOL WFOL-W4-350.00/2028, to be able to store minimum 6-year cooled fuel (Reference 1), remains unchanged. OPG had previously communicated the operational need for this activity in Reference 2.

To support the OPG Safe Storage Project for Pickering NGS, additional space in the Pickering NGS-B Irradiated Fuel Bay (IFB-B) is required in order to accept the discharged used fuel from the required core defuel. As PWMF is currently waiting for IFB-B used fuel to mature to the 10-year required period before transferring, there is a need to accept younger fuel to allow for the additional space. At this time, however, OPG is only licensed to process and store minimum 10-year cooled fuel at all its Nuclear Waste Facilities.

Attachment 1 provides the updated compliance matrix for the Nuclear Safety and Control Act, and the associated regulations required for the amendment of the PWMF WFOL to be able to store minimum 6-year cooled fuel.

Attachment 2 provides updates to enhance the information provided in Reference 1 to the description and key attributes of the storage of minimum 6-year cooled fuel and documents the licensing impact assessment on all 14 Safety and Control Areas of PWMF's WFOL. The following documents support this assessment:

- Enclosure 1 provides W-CORR-00531-01662, "*Storage of Dry Storage Containers (DSCs) containing less than 10 year old used fuel bundles at the*

Pickering Waste Management Facility (PWMF)" which was previously provided as Enclosure 1 of Reference 1,

- 92896-REP-01320-00012 R000, "*Safety Assessment Storing Lower Aged Fuel in PWMF SB3*" (previously provided as Enclosure 2 of Reference 1),
- 92896-REP-03200-00009 R000, "*Dose Rate Assessment Considering Lower Aged Fuel in PWMF SB3*" (previously provided as Enclosure 3 of Reference 1),
- Enclosure 2 provides 92896-MDR-79171-00001, "*Modification Design Requirements for Loading, Transferring, Processing and Storing Minimum 6-year-old Fuel at NSSP*".

00104-CORR-79171-0139942, "*Additional Information Concerning Thermal Gradients Pertaining to Dry Storage Containers (DSCs)*" is an assessment of the findings of a previously trialed Dry Storage Container (DSC) containing 6-year cooled fuel in 1998. CNSC staff requested this evaluation in Reference 3 and it was provided to CNSC staff as Enclosure 4 of Reference 1. Prior to that, OPG had submitted technical assessments to CNSC staff related to the storage of minimum 6-year cooled fuel (Enclosures 1 and 2 of Reference 4).

The design considerations of the storage of minimum 6-year cooled fuel complies with all applicable regulatory requirements. The safety assessment, which is referred to as the "safety case", demonstrates that the storage of minimum 6-year cooled fuel will have no significant impact on the continued safe operation of the PWMF, nor on public, employee, and environmental safety.

OPG is targeting to start loading DSCs with minimum 6-year cooled fuel by July 2024. After an initial loading of two to four DSCs to confirm temperature and dose measurements, a full campaign of loading minimum 6-year cooled fuel is targeted to commence by the first quarter of 2025.

In summary, OPG remains committed to the safe operation of the PWMF and re-affirms that minimum 6-year cooled fuel can be stored safely as presented in the associated safety case.

Should you have any questions, please contact Ms. Liliana Moraru, Manager, Regulatory Affairs - Strategic Projects, at (905) 260-4089 or liliana.moraru@opg.com.

Sincerely,

Kapil Aggarwal

Kapil Aggarwal, M. Eng., P. Eng
Vice President
Nuclear Sustainability Services
Ontario Power Generation Inc.

Encl

cc: N. Petseva - CNSC (Ottawa)
T. Kalindjian - CNSC (Ottawa)
R. Buhr - CNSC (Ottawa)
R. van Hoof - CNSC (Ottawa)

References:

1. OPG Letter, K. Aggarwal to D. Saumure, "OPG – Change Request Application for Amendment to the Pickering Waste Management Facility (PWMF) Waste Facility Operating Licence WFOL W4-350.00/2028 ", June 20, 2023, e-Doc# 7068976, CD# 92896-CORR-00531-01478.

2. OPG Letter, J. Van Wart to N. Greencorn, “Notice of Intent to Store Minimum 6-Year Old Used Fuel at the Pickering Waste Management Facility”, February 1, 2022, e-Doc# 6730024, CD# W-CORR-00531-01801.

3. CNSC Letter, T. Kalindjian to K. Aggarwal, “CNSC Staff Review of OPG Responses to CNSC Staff Comments – Proposal to Store Minimum 6-Year Old Cooled Used Fuel at the Pickering Waste Management Facility”, December 20, 2021, e-Doc# 6687357, CD# 92896-CORR-00531-01443.

4. OPG Letter, K. Aggarwal to T. Kalindjian, “OPG Response to CNSC Staff Comments on OPG’s Proposal to Store Minimum 6-Year Old Cooled Fuel at the Pickering Waste Management Facility”, June 14, 2021, e-Doc# 6585972, CD# 92896-CORR-00531-01430.

ATTACHMENT 1

OPG letter, K. Aggarwal to M. Bacon-Dussault, “OPG – Addendum to the Application for Amendment to the Pickering Waste Management Facility, Waste Facility Operating Licence WFOL-W4-350.00/2028”

CD# 92896-CORR-00531-01530 P

Licence Compliance Matrix – Nuclear Safety Control Act and Associated Regulations

Prepared By:	**C. Barua**
Checked By:	**K. Lynchahon**

ATTACHMENT 1

Licence Compliance Matrix – Nuclear Safety Control Act and Associated Regulations

This Attachment, along with the accompanying letter and Attachment 2 of this submission, provides the information required by the Nuclear Safety and Control Act and the applicable Nuclear Regulations made pursuant to the Act, and constitutes an application by OPG to amend the current Pickering Waste Management Facility (PWMF) Waste Facility Operating Licence WFOL-W4-350.00/2028.

The tables below are divided by applicable Regulation and demonstrate how OPG has addressed each applicable regulatory requirement of the subject Regulation.

Nuclear Safety and Control Act		
Section	**Requirement**	**OPG Response**
Licences		
24(2)	***Application*** *The Commission may issue, renew, suspend in whole or in part, amend, revoke, or replace a licence, or authorize its transfer on receipt of an application:* *(a) in the prescribed form;*	This submission (letter and attachments) provides the information required by the Nuclear Safety and Control Act (referred to as the Act) and the applicable Regulations made pursuant to the Act and provides supplemental information in support of OPG's application for licence amendment. This requirement has been met.
	(b) containing the prescribed information and undertakings and accompanied by the prescribed documents; and	See response above under clause 24 (2) (a).
	(c) accompanied by the prescribed fee.	OPG is in good standing with respect to the provision of CNSC licensing fees and will provide any additional fees associated with this WFOL amendment request, if requested.
24(4)	***Conditions for issuance, etc.*** *No licence may be issued, renewed, amended or replaced - and no authorization to transfer one given - unless, in the opinion of the Commission, the applicant:* *(a) is qualified to carry on the activity that the licence will authorize the licensee to carry on; and*	OPG understands that qualification will be determined through consideration by the Commission of this application and the associated supporting material, as well as deliberation through the Commission decision-making process. OPG is qualified to safely undertake the additional activities associated with the storage of minimum 6-year cooled fuel at PWMF.
	(b) will, in carrying on that activity, make adequate provision for the protection of the environment, the health and safety	Attachment 2 of this submission documents the assessments and provisions in support of the licence amendment request. Specifically:

Nuclear Safety and Control Act		
Section	**Requirement**	**OPG Response**
	of persons and the maintenance of national security and measures required to implement international obligations to which Canada has agreed.	• documents worker health and safety provisions. • documents assessments and impact on environmental protection. • documents the security considerations. • documents the impact on Canada's international obligations related to safeguards and nonproliferation
25	***Renewal, etc.*** *The Commission may, on its own motion, renew, suspend in whole or in part, amend, revoke or replace a licence under the prescribed conditions.*	OPG understands this requirement and will continue to comply.
26	***Prohibitions*** *Subject to the regulations, no person shall, except in accordance with a licence:* *(a) possess, transfer, import, export, use or abandon a nuclear substance, prescribed equipment or prescribed information;* *(b) mine, produce, refine, convert, enrich, process, reprocess, package, transport, manage, store or dispose of a nuclear substance;* *(c) produce or service prescribed equipment;* *(d) operate a dosimetry service for the purposes of this Act;* *(e) prepare a site for, construct, operate, modify, decommission or abandon a nuclear facility; or* *(f) construct, operate, decommission or abandon a nuclear-powered vehicle or bring a nuclear-powered vehicle into Canada.*	OPG staff understand these requirements and will continue to comply.

General Nuclear Safety and Control Regulations		
Section	**Requirement**	**OPG Response**
Licences – General Application Requirements		
3(1)	*An application for a licence shall contain the following information:* *(a) the applicant's name and business address;*	Applicant's name and business address: **Ontario Power Generation, Inc** **700 University Avenue,** **Toronto, Ontario, M5G 1Z5** Official Language: **English** Contact person, signing authority and licence holder: **Kapil Aggarwal** **Vice President** **Nuclear Sustainability Services,** **Ontario Power Generation** **Telephone: 416-402-6484**
	(b) the activity to be licensed and its purpose;	OPG requests an amendment to the PWMF WFOL, WFOL-W4-350.00/2028, to authorize the storage of minimum 6-year cooled fuel from Pickering NGS.
	(c) the name, maximum quantity and form of any nuclear substance to be encompassed by the licence;	100 Dry Storage Containers (DSCs) containing minimum 6-year cooled used fuel from Pickering NGS. These 100 DSCs are included in the current approved total for PWMF (and are not considered additional to the inventory).
	(d) a description of any nuclear facility, prescribed equipment or prescribed information to be encompassed by the licence;	A description of the PWMF is provided in Attachment 2 of this submission.
	(e) the proposed measures to ensure compliance with the Radiation Protection Regulations, the Nuclear Security Regulations and the Packaging and Transport of Nuclear Substances Regulations, 2015;	OPG understands this requirement and will remain in compliance with the current licence conditions documented in WFOL-W4-50.00/2028 and with the Radiation Protection Regulations, the Nuclear Security Regulations, and the Packaging and Transport of Nuclear Substances Regulations as described in Attachment 2 of this submission.

General Nuclear Safety and Control Regulations		
Section	**Requirement**	**OPG Response**
	(f) any proposed action level for the purpose of section 6 of the Radiation Protection Regulations;	The requested WFOL amendment will not require changes to the radiation protection action levels.
	(g) the proposed measures to control access to the site o the activity to be licensed and the nuclear substance, prescribed equipment or prescribed information;	The requested WFOL amendment will not require changes to the measures to control PWMF site access, the nuclear substance, prescribed equipment or prescribed information.
	(h) the proposed measures to prevent loss or illegal use, possession or removal of the nuclear substance, prescribed equipment or prescribed information;	The requested WFOL amendment will not require changes to the measures to prevent loss or illegal use, possession or removal of the nuclear substance, prescribed equipment or prescribed information.
	(i) a description and the results of any test, analysis or calculation performed to substantiate the information included in the application;	The requested WFOL amendment to authorize the storage of minimum 6-year cooled fuel at PWMF is supported by a robust safety case that is summarized in Attachment 2 of this submission.
	(j) the name, quantity, form, origin and volume of any radioactive waste or hazardous waste that may result from the activity to be licensed, including waste that may be stored, managed, processed or disposed of at the site of the activity to be licensed, and the proposed method for managing and disposing of that waste;	This waste will be managed in accordance with OPG's current programs and processes. No hazardous waste will be generated from the storage of minimum 6-year cooled fuel.
	(k) the applicant's organizational management structure insofar as it may bear on the applicant's compliance with the Act and the regulations made under the Act, including the internal allocation of functions, responsibilities and authority;	The organizational management structure will not change as a result of the requested licence amendment.
	(l) a description of any proposed financial guarantee relating to the activity to be licensed; and	OPG understands the regulatory requirements for a financial guarantee. The financial guarantee for PWMF will not change as a result of the requested WFOL amendment.
	(m) any other information required by the Act or the regulations made under the Act for the activity to be licensed and the nuclear substance, nuclear facility, prescribed equipment or	OPG understands this requirement and will continue to comply.

General Nuclear Safety and Control Regulations		
Section	**Requirement**	**OPG Response**
	prescribed information to be encompassed by the licence.	
(1.1)	*The Commission or a designated officer authorized under paragraph 37(2)(c) of the Act, may require any other information that is necessary to enable the Commission or the designated officer to determine whether the applicant* *(a) is qualified to carry on the activity to be licensed;* *(b) will, in carrying on that activity, make adequate provision for the protection of the environment, the health and safety of persons and the maintenance of national security and measures required to implement international obligations to which Canada has agreed.*	OPG understands this requirement and will continue to comply.
Application for Amendment, Revocation or Replacement of Licence		
6	*An application for the amendment, revocation or replacement of a licence shall contain the following information:* *(a) a description of the amendment, revocation or replacement and of the measures that will be taken and the methods and procedures that will be used to implement it;* *(b) a statement identifying the changes in the information contained in the most recent application for the licence;* *(c) a description of the nuclear substances, land, areas, buildings, structures, components, equipment and systems that will be affected by the amendment, revocation or replacement and of the manner in which they will be affected; and*	Attachment 2 of this submission documents the description of the amendment and of the measures that will be taken and the methods and procedures that will be used to implement it. Attachment 2 of this submission documents the changes that will be required to any licensing basis documents. The minimum 6-year cooled fuel will be stored within a specified array in PWMF Storage Building (SB) #3, a shielded building. The minimum 6-year cooled fuel will be stored in the same DSCs that are being used to store minimum 10-year cooled fuel. Initial loading of two to four DSCs containing minimum 6-year cooled fuel is proposed to commence in July 2024. After obtaining indicators related to temperature and dosage, the full campaign of storing minimum 6-year cooled fuel will commence.

General Nuclear Safety and Control Regulations		
Section	**Requirement**	**OPG Response**
	(d) the proposed starting date and the expected completion date of any modification encompassed by the application.	
Incorporation of Material in Application		
7	*An application for a licence or for the renewal, suspension in whole or in part, amendment, revocation or replacement of a licence may incorporate by reference any information that is included in a valid, expired or revoked licence.*	OPG understands and has provided applicable references to information contained in the existing licence and Licence Conditions Handbook.
Obligations		
12(1)	***Obligations of Licensees*** *Every licensee shall*	OPG understands the requirements and will continue to comply. Specifically:
	(*a) ensure the presence of a sufficient number of qualified workers to carry on the licensed activity safely and in accordance with the Act, the regulations made under the Act and the licence;*	The regulatory requirement will not change as a result of the requested licence amendment.
	(b) train the workers to carry on the licensed activity in accordance with the Act, the regulations made under the Act and the licence;	OPG staff will be trained on operation and maintenance activities associated with the requested licence amendment.
	(c) take all reasonable precautions to protect the environment and the health and safety of persons and to maintain the security of nuclear facilities and of nuclear substances;	Refer to section LC 9.1 in Attachment 2 of this submission for details on environmental protection. Refer to section LC 12.1 in Attachment 2 of this submission for further details on the impact to security.
	(d) provide the devices required by the Act, the regulations made under the Act and the licence and maintain them within the manufacturer's specifications;	OPG understands this requirement and will continue to comply.
	(e) require that every person at the site of the licensed activity use equipment, devices, clothing and procedures in accordance with the Act, the regulations made under the Act and the licence;	OPG understands this requirement and will continue to comply.

General Nuclear Safety and Control Regulations		
Section	**Requirement**	**OPG Response**
	(f) take all reasonable precautions to control the release of radioactive nuclear substances or hazardous substances within the site of the *licensed activity and into the environment as a result of the licensed activity;*	OPG understands this requirement and will continue to comply. Refer to section LC 9.1 in Attachment 2 for further details on security.
	(g*) implement measures for alerting the licensee to the illegal use or removal of a nuclear substance, prescribed equipment or prescribed information, or the illegal use of a nuclear facility;*	OPG understands this requirement and will continue to comply. Refer to section LC 13.1 in Attachment 2 of this submission for further details on security.
	(h) implement measures for alerting the licensee to acts of sabotage or attempted sabotage anywhere at the site of the licensed activity;	OPG understands this requirement and will continue to comply.
	(i) take all necessary measures to facilitate Canada's compliance with any applicable safeguards agreement;	OPG understands this requirement and will continue to comply. Refer to section LC 13.1 in Attachment 2 of this submission for further details on safeguards.
	(j) instruct the workers on the physical security program at the site of the licensed activity and on their obligations under that program;	OPG understands this requirement and will continue to comply. Refer to section LC 12.1 in Attachment 2 of this submission for further details on security.
	(k) keep a copy of the Act and the regulations made under the Act that apply to the licensed activity readily available for consultation by the workers.	OPG understands this requirement and will continue to comply.
12(2)	*Every licensee who receives a request from the Commission or a person who is authorized by the Commission for the purpose of this subsection, to conduct a test, analysis, inventory or inspection in respect of the licensed activity or to review or to modify a design, to modify equipment, to modify procedures or to install a new system or new equipment shall file, within the time specified in the request, a report with the Commission that contains the following information:*	OPG understands this requirement and will continue to comply. Testing and commissioning procedures and reports associated with the storage of minimum 6-year cooled fuel will be made available to facilitate the regulatory role of CNSC staff.

General Nuclear Safety and Control Regulations		
Section	**Requirement**	**OPG Response**
	(a) confirmation that the request will or will not be carried out or will be carried out in part; *(b) any action that the licensee has taken to carry out the request or any part of it;* *(c) any reasons why the request or any part of it will not be carried out;* *(d) any proposed alternative means to achieve the objectives of the request; and* *(e) any proposed alternative period within which the licensee proposes to carry out the request.*	
	Transfers	
13	*No licensee shall transfer a nuclear substance, prescribed equipment or prescribed information to a person who does not hold the licence, if any, that is required to possess the nuclear substance, prescribed equipment or prescribed information by the Act and the regulations made under the Act*.	OPG understands this requirement and will continue to comply.
	Notice of Licence	
14	*(1) Every licensee other than a licensee who is conducting field operations shall post, at the location specified in the licence or, if no location is specified in the licence, in a conspicuous place at the site of the licensed activity,* *(a) a copy of the licence, with or without the licence number, and a notice indicating the place where any record referred to in the licence may be consulted; or* *(b) a notice containing* *(i) the name of the licensee,* *(ii) a description of the licensed activity,*	OPG understands this requirement and will continue to comply with this requirement.

General Nuclear Safety and Control Regulations		
Section	**Requirement**	**OPG Response**
	(iii) a description of the nuclear substance, nuclear facility or prescribed equipment encompassed by the licence, and *(iv) a statement of the location of the licence and any record referred to in it.* *(2) Every licensee who is conducting field operations shall keep a copy of the licence at the place where the field operations are being conducted.* *(3) Subsections (1) and (2) do not apply to a licensee in respect of* *(a) a licence to import or export a nuclear substance, prescribed equipment or prescribed information;* *(b) a licence to transport a nuclear substance; or* *(c) a licence to abandon a nuclear substance, a nuclear facility, prescribed equipment or prescribed information.*	
Publication of Health and Safety Information		
16	*(1) Every licensee shall make available to all workers the health and safety information with respect to their workplace that has been collected by the licensee in accordance with the Act, the regulations made under the Act and the licence.* *(2) Subsection (1) does not apply in respect of personal dose records and prescribed information.*	OPG understands this requirement and will continue to comply. OPG's Health and Safety Policy is posted on the OPG intranet website.
Obligations of Workers		
17	*Every worker shall:*	OPG understands this requirement and will continue to comply.

General Nuclear Safety and Control Regulations		
Section	**Requirement**	**OPG Response**
	(a) use equipment, devices, facilities and clothing for protecting the environment or the health and safety of persons, or for determining doses of radiation, dose rates or concentrations of radioactive nuclear substances, in a responsible and reasonable manner and in accordance with the Act, the regulations made under the Act and the licence; *(b) comply with the measures established by the licensee to protect the environment and the health and safety of persons, maintain security, control the levels and doses of radiation, and control releases of radioactive nuclear substances and hazardous substances into the environment;* *(c) promptly inform the licensee or the worker's supervisor of any situation in which the worker believes there may be* *(i) a significant increase in the risk to the environment or the health and safety of persons,* *(ii) a threat to the maintenance of the security of nuclear facilities and of nuclear substances or an incident with respect to such security,* *(iii) a failure to comply with the Act, the regulations made under the Act or the licence,* *(iv) an act of sabotage, theft, loss or illegal use or possession of a nuclear substance, prescribed equipment or prescribed information, or* *(v) a release into the environment of a quantity of a radioactive nuclear substance or hazardous substance that*	

General Nuclear Safety and Control Regulations		
Section	**Requirement**	**OPG Response**
	has not been authorized by the licensee; *(d) observe and obey all notices and warning signs posted by the licensee in accordance with the Radiation Protection Regulations; and* *(e) take all reasonable precautions to ensure the worker's own safety, the safety of the other persons at the site of the licensed activity, the protection of the environment, the protection of the public and the maintenance of the security of nuclear facilities and of nuclear substances.*	

Class 1 Nuclear Facility Regulations		
Section	**Requirement**	**OPG Response**
	Licence Applications – General Requirements	
3	*An application for a licence in respect of a Class I nuclear facility, other than a licence to abandon, shall contain the following information in addition to the information required by section 3 of the General Nuclear Safety and Control Regulations:* *(a) a description of the site of the activity to be licensed, including the location of any exclusion zone and any structures within that zone;*	The requested WFOL amendment will not require changes to the description or plans of the PWMF site from the licence renewal application (Reference [1-1]).
	(b) plans showing the location, perimeter, areas, structures and systems of the nuclear facility;	
	(c) evidence that the applicant is the owner of the site or has authority from the owner of the site to carry on the activity to be licensed;	The requested WFOL amendment will not require changes to site ownership as provided in Attachment 1 of Reference [1-1].
	(d) the proposed management system for the activity to be licensed, including measures to promote and support safety culture;	OPG understands this requirement and will continue to comply. Refer to section LC 1.1 in Attachment 2 of this submission for further details on management system.
	(d.1) the proposed human performance program for the activity to be licensed, including measures to ensure workers' fitness for duty.	OPG understands this requirement and will continue to comply. Refer to section LC 2.1 in Attachment 2 of this submission for further details on human performance and fitness for duty.
	(e) the name, form, characteristics and quantity of any hazardous substances that may be on the site while the activity to be licensed is carried on;	The requested WFOL amendment will not require changes to the name, form, characteristics and quantity of any hazardous substances from the licence renewal application (Reference [1-1]).
	(f) the proposed worker health and safety policies and procedures;	OPG understands this requirement and will continue to comply. Refer to sections LC 7.1 and LC 8.1 in Attachment 2 of this submission for further details on radiation protection and conventional health and safety respectively.

Class 1 Nuclear Facility Regulations		
Section	**Requirement**	**OPG Response**
	(g) the proposed environmental protection policies and procedures;	OPG understands this requirement and will continue to comply. Refer to section LC 9.1 in Attachment 2 of this submission for further details on environmental protection including environmental monitoring.
	(h) the proposed effluent and environmental monitoring programs;	
	(i) if the application is in respect of a nuclear facility referred to in paragraph 2(b) of the Nuclear Security Regulations, the information required by section 3 of those Regulations;	OPG understands this requirement and will continue to comply. Refer to section LC 12.1 in Attachment 2 of this submission for further details on security program.
	(j) the proposed program to inform persons living in the vicinity of the site of the general nature and characteristics of the anticipated effects on the environment and the health and safety of persons that may result from the activity to be licensed; and	The requested WFOL amendment will not require changes to the community relations or Indigenous Nations engagement programs. Refer to sections 3.2 and 3.3 of Attachment 3 of the licence renewal application (Reference [1-1]).
	(k) the proposed plan for the decommissioning of the nuclear facility or of the site.	OPG understands this requirement and will continue to comply. Refer to section LC 11.2 in Attachment 2 of this submission for further details on decommissioning plans.
Licence to Operate		
6	*An application for a licence to operate a Class 1 nuclear facility shall contain the following information in addition to the information required by section 3:* *(a) a description of the structures at the nuclear facility, including their design and their design operating conditions;* *(b) a description of the systems and equipment at the nuclear facility, including their design and their design operating conditions;*	The requested WFOL amendment will not require changes to the description, design or design operating conditions of PWMF structures or systems. Refer to sections 1.0 and 2.5 of Attachment 3 of the licence renewal application (Reference [1-1]).
	(c) a final safety analysis report demonstrating the adequacy of the design of the nuclear facility;	OPG understands this requirement and will continue to comply.

Class 1 Nuclear Facility Regulations		
Section	**Requirement**	**OPG Response**
		Refer to section LC 4.1 in Attachment 2 of this submission for further details on safety analysis.
	(d) the proposed measures, policies, methods and procedures for operating and maintaining the nuclear facility;	OPG understands this requirement and will continue to comply. Refer to section LC 3.1 in Attachment 2 of this submission for further details on operating performance.
	(e) the proposed procedures for handling, storing, loading and transporting nuclear substances and hazardous substances;	OPG understands this requirement and will continue to comply. Refer to section LC 14.1 in Attachment 2 of this submission for further details on packaging and transport.
	(f) the proposed measures to facilitate Canada's compliance with any applicable safeguards agreement;	OPG understands this requirement and will continue to comply. Refer to section LC 13.1 in Attachment 2 of this submission for further details on safeguards.
	(g) the proposed commissioning program for the systems and equipment that will be used at the nuclear facility;	OPG understands this requirement and will continue to comply. Refer to section LC 3.1 in Attachment 2 of this submission for further details on operating performance.
	(h) the effects on the environment and the health and safety of persons that may result from the operation and decommissioning of the nuclear facility, and the measures that will be taken to prevent or mitigate those effects;	OPG understands this requirement and will continue to comply. Refer to section LC 7.1, LC 8.1 and LC 9.1 in Attachment 2 of this submission for further details on radiation protection, conventional health and safety respectively and environmental protection.

Class 1 Nuclear Facility Regulations		
Section	**Requirement**	**OPG Response**
	(i) the proposed location of points of release, the proposed maximum quantities and concentrations, and the anticipated volume and flow rate of releases of nuclear substances and hazardous substances into the environment, including their physical, chemical and radiological characteristics; *(j) the proposed measures to control releases of nuclear substances and hazardous substances into the environment;*	OPG understands this requirement and will continue to comply. Refer to section LC 9.1 in Attachment 2 of this submission for further details on environmental protection.
	(k) the proposed measures to prevent or mitigate the effects of accidental releases of nuclear substances and hazardous substances on the environment, the health and safety of persons and the maintenance of national security, including measures to *(i) assist off-site authorities in planning and preparing to limit the effects of an accidental release,* *(ii) notify off-site authorities of an accidental release or the imminence of an accidental release,* *(iii) report information to off-site authorities during and after an accidental release,* *(iv) assist off-site authorities in dealing with the effects of an accidental release, and* *(v) test the implementation of the measures to prevent or mitigate the effects of an accidental release;*	OPG understands this requirement and will continue to comply. Refer to section LC 10.1 in Attachment 2 of this submission for further details on emergency preparedness.

Class 1 Nuclear Facility Regulations		
Section	**Requirement**	**OPG Response**
	(l) the proposed measures to prevent acts of sabotage or attempted sabotage at the nuclear facility, including measures to alert the licensee to such acts;	OPG understands this requirement and will continue to comply. Refer to section LC 12.1 in Attachment 2 of this submission for further details on security program.
	(m) the proposed responsibilities of and qualification requirements and training program for workers, including the procedures for the requalification of workers; and *(n) the results that have been achieved in implementing the program for recruiting, training and qualifying workers in respect of the operation and maintenance of the nuclear facility.*	OPG understands this requirement and will continue to comply. Refer to section LC 2.2 in Attachment 2 of this submission for further details on training program.

Radiation Protection Regulations		
Section	**Requirement**	**OPG Response**
4	*Every licensee must implement a radiation protection program and must, as part of that program,* *(a) keep the effective dose and equivalent dose received by and committed to persons as low as reasonably achievable, taking into account social and economic factors, through the implementation of* *(i) management control over work practices,* *(ii) personnel qualification and training,* *(iii) control of occupational and public exposure to radiation, and* *(iv) planning for unusual situations; and* *(b) ascertain the quantity and concentration of any nuclear substance released as a result of the licensed activity* *(i) by direct measurement as a result of monitoring, or* *(ii) if the time and resources required for direct measurement as a result of monitoring outweigh the usefulness of ascertaining the quantity and concentration using that method, by estimating them.*	OPG has a well-established radiation protection program that complies with all elements of the Radiation Protection Regulations. Further details are provided in Section LC 7.1 on OPG's Radiation Protection considerations for the loading of minimum 6-year cooled fuel.

Nuclear Security Regulations
OPG will continue to adhere to all facets of the Nuclear Security Regulations and keep in place all current security processes in the handling and storage of used fuel from Pickering NGS.

References: [1-1]. OPG letter, L. Swami to M. Leblanc, "Application for Renewal of Pickering Waste Management Facility", CD# 92896-CORR-00531-01031, October 28, 2016.

ATTACHMENT 2

OPG letter, K. Aggarwal to M. Bacon-Dussault, “OPG – Addendum to the Application for Amendment to the Pickering Waste Management Facility, Waste Facility Operating Licence WFOL-W4-350.00/2028”

CD# 92896-CORR-00531-01530 P

Licence Amendment Application for the Storage of Minimum 6-Year Cooled Fuel at the Pickering Waste Management Facility

Prepared By: **C. Barua**

Checked By: **H. Innis/K. Lynchahon**

ATTACHMENT 2

ONTARIO POWER GENERATION

LICENCE AMENDMENT APPLICATION FOR THE STORAGE OF MINIMUM 6-YEAR COOLED FUEL AT THE PICKERING WASTE MANAGEMENT FACILITY

Introduction

Background

The purpose of this attachment is to provide information in support of OPG's request for amendment to the Pickering Waste Management (PWMF) Waste Facility Operating Licence (WFOL), WFOL-W4-350.00/2028, to allow for the storage of minimum 6-year cooled fuel from Pickering Nuclear Generating Station (PNGS).

Description of PWMF – Used Fuel Dry Storage

The PWMF is located within the traditional territory of the Michi Saagiig Anishinaabe people. These lands are covered by the Williams Treaty between Canada and the Mississauga and Chippewa Nations. The PWMF operates under a Waste Facility Operating Licence (WFOL). At the PWMF, OPG processes and stores dry storage containers (DSCs) containing used nuclear fuel (high-level radioactive waste) generated at the PNGS, that has cooled for a minimum of ten years in the fuel bays at PNGS.

The dry storage of used fuel at the PWMF spans over 2 physically separate areas - Phase I and Phase II - within the overall boundary of the Pickering site. Phase I is located within the protected area of the PNGS and consists of the DSC Processing Building and two DSC storage buildings (Storage Buildings #1 and #2). Phase II of the PWMF is located northeast of Phase I and is contained within its own protected area, but within the boundary of the Pickering site. Phase II contains Storage Building #3 and #4. The PWMF currently has the capacity to store 1,778 DSCs. The transfer route of the loaded DSCs from the PWMF Phase I to the PWMF Phase II is solely on OPG property.

The information provided in this Attachment is divided into three sections as follows:

Section 1: Provides the need to store minimum 6-year cooled fuel at PWMF to support the Safe Storage Project at PNGS Units 5-8, and operational considerations for this activity.

Section 2: Summarizes regulatory compliance for the storage of minimum 6-year cooled fuel at PWMF and impact on OPG's governance, programs and processes for each of PWMF's WFOL's fourteen (14) Safety and Control Areas (SCA).

Section 3: Summarizes public, Indigenous Nations and Métis engagement related to this application for a licence amendment.

OPG is responsible for the continued safe operation of the PWMF and confirms that the storage of minimum 6-year cooled fuel will be implemented based on a robust safety case and proven engineering methods.

OPG has concluded that the proposed activities to support the storage of minimum 6-year cooled fuel will not compromise continued safe operation of the PWMF. OPG has and will continue to follow a robust and well-established Engineering Change Control (ECC) process and will continue to provide information to CNSC staff to assist in fulfillment of their regulatory oversight role.

The storage of minimum 6-year cooled fuel at PWMF is an important initiative to support the OPG Safe Storage Project for PNGS. The objective is to **only** accept minimum 6-year cooled fuel at PWMF from PNGS Units 5-8 (and **not** PNGS Units 1 and 4).

Section 1: Summary of Proposed Activity Requiring Licence Amendment

To support the OPG Safe Storage Project for PNGS, additional space in the PNGS-B Irradiated Fuel Bay (IFB-B) is required in order to accept the discharged used fuel from the required core defuel. As PWMF is currently waiting for IFB-B used fuel to mature to the 10-year required period before transferring, there is a need to accept younger fuel (minimum 6-year cooled fuel) to allow for the additional space. However, OPG is currently licensed to only process minimum 10-year cooled fuel at all Nuclear Waste Facilities. In order to store younger (i.e., minimum 6-year cooled fuel), OPG must apply for a License Amendment for the PWMF's WFOL (WFOL-W4-350.00/2028).

Master EC# 154806, "Loading, Processing and Storing a Maximum of 100 Dry Storage Containers (DSCs) (at one time) that Contain Used Fuel with a Minimum Cooling Period of 6 Years of Age in PWMF" was initiated to support the PNGS-B and PWMF operational need. The modification includes loading, transferring, processing and storage of up to 100 DSCs from the IFB-B that contain used fuel with a minimum cooling period of 6 years as well as the rearrangement of a number of the existing DSCs in Storage Building 3 (SB3) to accommodate the incoming DSCs. The younger used fuel will be loaded into DSCs in the IFB-B, transferred to the PWMF for processing, moved into the IAEA Surveillance Area in Storage Building 1 (SB1) for the application of safeguard seals and transferred for storage into SB3. Once all fuel in a DSC reaches the minimum cooling period of 10 years, the DSC can be treated the same as existing DSCs in the Used Fuel Storage Buildings at PWMF (and would not be considered part of the inventory of 100 DSCs containing minimum 6-year cooled fuel). Based on the analysis performed, it was determined that no design changes are required to the DSC to accept the storage of minimum 6-year cooled fuel within the DSC and stored in the PWMF storage buildings.

OPG targets to start commissioning DSCs containing minimum 6-year cooled fuel in July 2024, with the aim to initially gather predictive indicators around temperature and dosage. If this initial campaign proves successful (indicators are agreeable with modelling predictions) and doesn't present unforeseen challenges, the full campaign to store the minimum 6-year cooled fuel would commence in Q1 of 2025.

Safety Case

Safety is OPG's number one priority, proven over many years of both reactor operation and radioactive waste management and storage. OPG is responsible for continued safe operation of the PWMF and confirms that the minimum 6-year cooled fuel modifications at PWMF will be implemented based on a robust safety case and in accordance with OPG's Engineering Change Control process, which is supported by safety assessments 92896-REP-01320-

00012, "*Safety Assessment Storing Lower Aged Fuel in PWMF SB3*" and 92896-REP-03200-00009, "*Dose Rate Assessment Considering Lower Aged Fuel in PWMF SB3*" (Enclosures 2 and 3 of Reference [2-1] respectively) that demonstrate continued safe facility operation, public and worker safety, and environmental protection.

The safety case for the storage of minimum 6-year cooled fuel at PWMF can be defined based on the following elements:

1) Design: OPG has and will continue to follow its Engineering Change Control process, as described in N-PROG-MP-0001, "*Engineering Change Control*", for ensuring the design complies with applicable PWMF Licence Condition Handbook, LCH-W4-350.00/2028, regulatoryrequirements and that configuration management for the station is maintained.

2) Continued Safe Operation: Safety analysis (Enclosure 1 of this submission) demonstrates that the storage of minimum 6-year cooled fuel at PWMF will have a negligible effect on safe operation of PWMF, and on public and worker safety.

3) Environmental Protection: An assessment of existing environmental-related submissions to the CNSC (environmental assessments, environmental risk assessment and predictive environmental effects assessment) (Enclosure 1 of this submission) concludes that the storage of minimum 6-year cooled fuel at PWMF will have negligible impact on the environment.

4) Licensing Basis: The storage of minimum 6-year cooled fuel at PWMF will have negligible impact on PWMF's licensing basis, governance, programs and processes. Attachment 1 provides the compliance matrix for the "*Nuclear Safety Control Act*" and associated regulations required for the amendment of the PWMF WFOL to add the proposed new activity.

Overall, there are no notable safety or operational issues that result from storing minimum 6-year cooled fuel at PWMF.

Section 2: Safety and Control Areas

This section provides the impact assessment of the proposed new activity on PWMF's licensing basis for each of the PWMF WFOL Safety and Control Areas (SCAs).

OPG is responsible for the continued safe operation of the PWMF and confirms that all modifications made with respect to the storage of minimum 6-year cooled fuel, will be implemented based on a robust safety case and in accordance with OPG's ECC process and that is supported by safety assessments, which demonstrate continued safe operation of the PWMF, public safety, worker safety and environmental protection.

LC 1.1 Management System

Licence Condition 1.1 states "*the licensee shall implement and maintain a management system*" and the details in the PWMF Licence Conditions Handbook (LCH) outline the regulatory requirements. The information provided in the last PWMF licence application is still valid.

OPG's proven Nuclear Management System provides a framework that establishes the processes and programs required to ensure OPG achieves its safety objectives, continuously monitors its performance against these objectives, and fosters a healthy safety culture.

List of Management System Related Regulatory Requirements

Licensing Basis Document Title	Document Number	Impact from the Storage of Minimum 6-Year Cooled Fuel
Management System Requirements for Nuclear Facilities	CSA N286 (2012)	Continued compliance as applied to all aspects of operation and modifications at PWMF.

Quality Assurance, CSA Standard N286-12 Compliance

PWMF is compliant with CSA Standard N286-12, "*Management system requirements for nuclear facilities*". The Nuclear Charter, N-CHAR-AS-0002, "*Nuclear Management System*", establishes the Nuclear Management System for OPG Nuclear. The Nuclear Management System will not change as a result of the proposed storage of minimum 6-year cooled fuel at PWMF.

Nuclear Safety Culture

OPG routinely monitors the health of its nuclear safety culture through Nuclear Safety Monitoring Panels. These panels were established based on the industry best practices documents in the Nuclear Energy Institute's NEI-09-07, "*Fostering* a *Strong Nuclear Safety Culture*"*.* The Nuclear Safety Monitoring Panel examines information from a variety of the processes that have been implemented, such as the corrective action process, the human performance program, audits and self-assessments, external inspections such as CNSC inspections or industry evaluations, employee concerns, and business performance monitoring. This information is evaluated against the traits of a healthy nuclear safety culture to identify strengths and areas for focused attention within the organization. The panel is composed of all of the managers and senior leadership within NSS. The panel evaluates the information and approves any initiatives or reinforces communications as needed.

Impact of the Storage of Minimum 6-Year Cooled Fuel on OPG Governance, Programs and Processes

The table below provides the list of OPG governance, programs and processes that form the licensing basis for PWMF's Management System and identifies the impact of storing minimum 6-year cooled fuel on these programs and processes.

Impact of the Storage of Minimum 6-year Cooled Fuel on PWMF's Management System Licensing Basis Documents

OPG Management System Licensing Basis Document Title	OPG Document Number	Impact from Storage of Minimum 6-Year Cooled Fuel
Items and Services Management	OPG-PROG-0009	No Change
Health and Safety Managed Systems	OPG-PROG-0005	No Change
Nuclear Management Systems Organization	N-STD-AS-0020	No Change
Nuclear Safety Culture Assessment	N-PROC-AS-0077	No Change
Nuclear Safety Oversight	N-STD-AS-0023	No Change
Nuclear Safety Policy	N-POL-0001	No Change
Nuclear Management System	N-CHAR-AS-0002	No Change

LC 1.2 Management of Contractors

Licence Condition 1.2 states "*the licensee shall ensure that every contractor at the facility complies with this licence*" and the details in the PWMF Licence Conditions Handbook (LCH) outline the regulatory requirements. The information provided in the last PWMF licence application is still valid.

Vendors and contractors are qualified by OPG Supply Chain Quality Services under a process that ensures that the contractors have developed and implemented a management system that meets the applicable requirements outlined in the CSA Standard N286 series of standards. OPG is ultimately responsible for ensuring that all on-site contractor activities comply with OPG's safety requirements. Day-to-day operations at the PWMF are generally maintained by full-time staff of OPG.

LC 2.1 Human Performance Program

Licence Condition 2.1 states "*the licensee shall implement and maintain a human performance program*" and the details in the PWMF Licence Conditions Handbook (LCH) outline the regulatory requirements. The information provided in the last PWMF licence application is still valid.

Human performance relates to reducing the likelihood of human error in work activities. It refers to the outcome of human behaviour, functions and actions in a specified environment, reflecting the ability of workers and management to meet the system's defined performance under the conditions in which the system will be employed.

List of Human Performance Management Related Regulatory Requirements

Licensing Basis Document Title	Document Number	Impact from Storage of Minimum 6-Year Cooled Fuel
Fitness for Duty: Managing Worker Fatigue	CNSC REGDOC-2.2.4 (2017)	Continued compliance, no impact.
Fitness for Duty, Volume II: Managing Alcohol and Drug Use, Version 2	CNSC REGDOC- 2.2.4 (2017)	Continued compliance, no Impact.
Safety Culture	CNSC REGDOC-2.1.2 (2018)	Continued compliance, no impact.

Human Performance Program

The objective of OPG's Human Performance program, N-PROG-AS-0002, "*Human Performance*" is to reduce human performance events and errors by managing defences in pursuit of zero events of consequence.

The Human Performance program integrates proactive (prevention) and reactive (detection and correction) human performance initiatives, which includes the following:

- Providing oversight and mentoring of department human performance.
- Identifying emerging human performance issues and determining strategies for related improvement.
- Approving site-wide human performance improvement initiatives and measures and overseeing implementation progress.
- Use of the human performance toolbox, prevent event tools.
- Identifying and implementing human performance improvement communication, education, and training opportunities.

The site strategic plan provides guidance to the leadership team on the requirements for the development and implementation of an integrated site and department human performance strategic plan. Department managers and supervisors develop a human performance plan that sets clear direction and priorities to achieve common goals.

Fitness for Duty

As part of OPG's fitness for duty program, OPG has in place a Continuous Behaviour Observation Program which trains supervisors and managers to monitor workers for signs of fatigue or other factors which could adversely impact worker performance.

OPG has in place hours of work requirements that are documented in N-PROC-OP-0047, *"Hours of Work Limits and Managing Worker Fatigue"* that sets limits for the number of hours within a specified time period that station staff can work. The limits, which are in place to guard against fatigue in the workplace, are very strict in comparison to other jurisdictions.

The storage of minimum 6-year cooled fuel will not impact OPG's fitness for duty program or compliance to hours-of-work requirements.

Impact of the Storage of Minimum 6-year Cooled Fuel on PWMF's Human Performance Program Licensing Basis Documents

The table below provides the list of OPG governance, programs and processes that form the licensing basis for PWMF's Human Performance program and identifies the impact of the storage of minimum 6-year cooled fuel on these programs and processes.

Impact of Minimum 6-year Cooled Fuel on PWMF's Human Performance Management Licensing Basis Documents

OPG Human Performance Licensing Basis Document Title	OPG Document Number	Impact from Storage of Minimum 6-Year Cooled Fuel
Human Performance	N-PROG-AS-0002	No Change
Hours of Work Limits and Managing Worker Fatigue	N-PROC-OP-0047	No Change

LC 2.2. Training Program

Licence Condition 2.2 states "*the licensee shall implement and maintain a training program*" and the details in the PWMF Licence Conditions Handbook (LCH) outline the regulatory requirements. The information provided in the last PWMF licence application is still valid.

Personnel at the PWMF will be fully trained on the loading of minimum 6-year year cooled fuel and also on mitigative measures for backout when required. All required staff will be fully trained before the first DSC containing minimum 6-year cooled fuel is commissioned.

List of Training Related Regulatory Requirements

Licensing Basis Document Title	Document Number	Impact from Storage of Minimum 6-Year Cooled Fuel
Personnel Training	CNSC REGDOC-2.2.2 (2016)	Continued compliance, no impact.

Impact of the Storage of Minimum 6-year Cooled Fuel on PWMF's Training Program Licensing Basis Documents

The table below provides the list of OPG governance, programs and processes that form the licensing basis for PWMF's Training program and identifies the impact of the storage of minimum 6-year cooled fuel on these programs and processes.

Impact of Minimum 6-year Cooled Fuel on PWMF's Training Program Licensing Basis Documents

OPG Human Performance Licensing Basis Document Title	OPG Document Number	Impact from Storage of Minimum 6-Year Cooled Fuel
Systematic Approach to Training	N-PROC-TR-0008	No Change
Training	N-PROG-TR-0005	No Change

LC 3.1 Operating Performance

Licence Condition 3.1 states "*the licensee shall implement and maintain an operating program, which includes a set of operating limits*" and the details in the PWMF Licence Conditions Handbook (LCH) outline the regulatory requirements. The information provided in the last PWMF licence application is still valid.

Operational Analysis

Processing minimum 6-year cooled fuel is essentially the same as processing 10-year cooled fuel. The trialing of the initial two to four DSCs will be tested for various indicators, including temperature and dosage. That may dictate required changes to staff requirements around personal protective equipment, worker proximity to hazards and instruments used (which would then be reflected in the appropriate operational procedures). Loading of DSCs is not expected to change in any way. DSCs that contain minimum 6-year cooled fuel have been analyzed for the anticipated temperatures throughout the DSC. Based on conservative bounding scenario assumptions, it has been conservatively identified that contact temperatures could potentially reach approximately 85 degrees Celsius (°C), which impacts worker safety in handling the DSC. The increased temperatures potentially impact interfacing equipment such as Advanced Inspection and Maintenance (AIM) equipment and International Atomic Energy Agency (IAEA) equipment including seals and NDE profiling.

Based on OPEX from 1998, DSC 0024 contained four full modules (384 bundles) of 6-year cooled fuel and had temperature probes fixed to the DSC. Temperature measurements were much lower than the conservative design analysis from 2022. These temperatures are documented in OPG Controlled Document 00104-CORR-79171-0139942 "*Additional*

Information Concerning: Thermal Gradients Pertaining to Dry Storage Containers (DSCs)" (Enclosure 4 of Reference [2-1]) (2005) and summarized in Figure 1 below. Based on this OPEX, it is anticipated that contact temperatures will not be as high as analyzed.

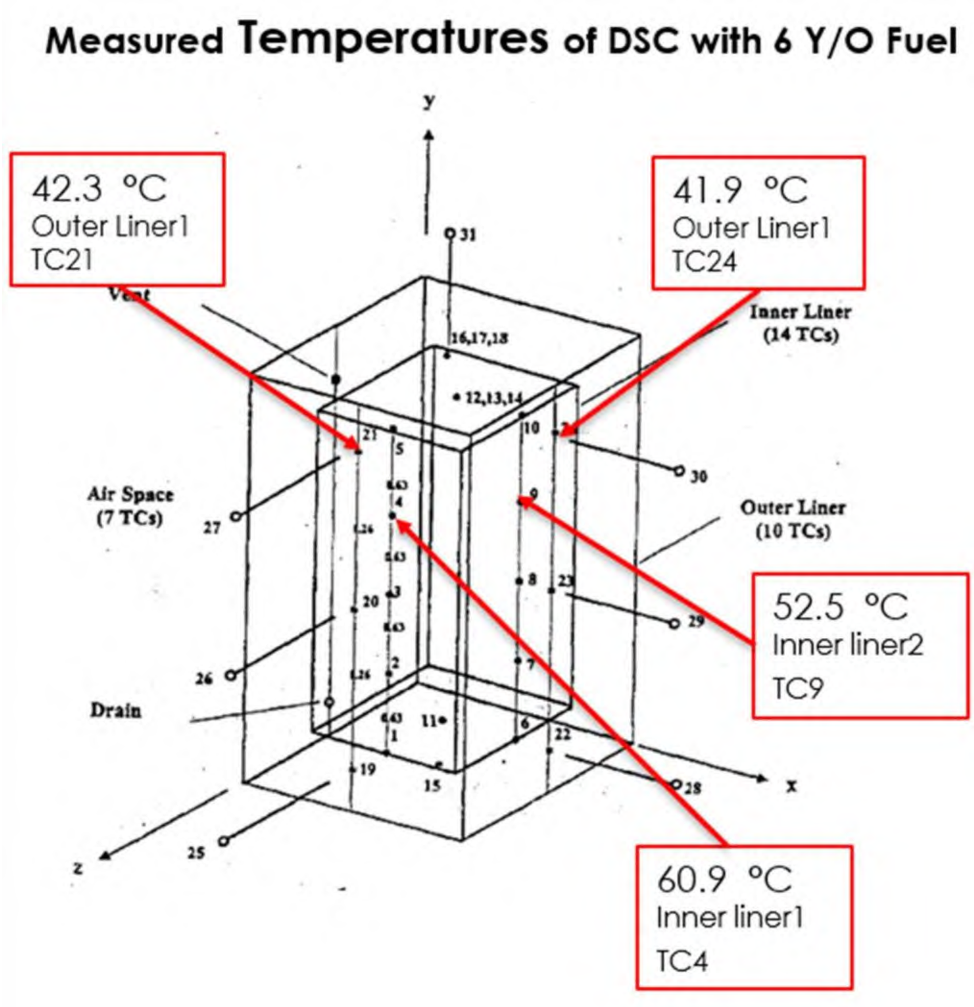

Figure 1: Measured Temperatures in DSC 0024

Commissioning Plan

Operationally, only one DSC is required to be loaded with 6-year cooled fuel to commission the modification. However, to avoid reverse loading (see Reverse Loading below), a conservative approach is recommended to be used. A potential option would be to load and vacuum dry the commissioning DSCs, starting with 9-year cooled fuel and working down to 6-year cooled fuel while measuring temperatures and dose rates. Based on OPG report with Controlled Document 92896-REP-79171-00001, "*NSATD-0232 Thermal Analyses for Pickering Waste Management Facility Storage Building 3*", the time taken for the outer liner of the DSC to reach equilibrium temperature is of the order of three weeks on average. Therefore, this option will take several months to complete the commissioning.

Acceptable temperatures are driven by Advance Inspection and Maintenance (AIM) and IAEA equipment at specific DSC locations outlined in Table 1 below:

Table 1 - IAEA/AIM Equipment Temperature Limits

Container Location	Equipment	Temp. Limit	Analyzed Temp.	OPEX Temp. DSC 0024
Weld Flange	AIM – Phased Array Ultrasonic Testing – (PAUT)	50 °C	~ 85 °C	~ 45 °C
Weld Flange	IAEA - Laser Container Mapping Verification	Deformation ~60 °C (Estimate)	~ 85 °C	~ 45 °C
Seal Tubes	IAEA -Fiber Optic Seals	Degradation ~70 °C (Estimate)	~100 °C	< 62 °C

IAEA temperature limits in Table 1 are estimates since they are not allowed to be identified. Estimates listed in Table 1 are based on discussions with IAEA.

AIM Equipment

As part of the commissioning, the intent is to ensure that the temperatures meet AIM equipment requirements before proceeding with the welding and continuation of processing the DSC to interim storage. The AIM equipment has a temperature limitation 50°C, shown in Table 1 above. If temperatures are measured less than 50°C, then nothing changes except conventional and Radiation Protection (RP) safety aspects. The AIM Acquisition Procedure would remain unaltered and there would be no issue.

Options have been considered for cooling the DSC flange if temperatures are measured in excess 50°C. Details on flange cooling are discussed below. If temperatures exceed 50°C, and the flange cooling methods are ineffective then the DSC will be Reverse loaded (discussed below).

Flange cooling: options for cooling the DSC flange are available if temperatures are measured in excess 50°C. Having an effective means to cool the DSC temperatures reduces the risk of having to resort to the back-out option (Reverse Loading).

IAEA Equipment

Temperature limits for IAEA are listed in Table 1 above. The impact of higher temperatures on IAEA safeguards and security interfacing equipment is being evaluated and discussion with the IAEA and CNSC is in progress. There is a risk that some IAEA equipment used for the sealing processes is not designed for the increased temperatures that could be observed.

Current proposal to the IAEA is to:

- Load and Vacuum Dry commissioning DSC with minimum 6-year cooled fuel.
- Within Camera View – Allow DSC to reach maximum temperature (not welded).
- Allow for residency time of three weeks to allow for DSC to reach equilibrium temperature, measure temperatures and doses.

- If temperatures are conducive for Fiber Optic seals: complete DSC processing. Confirm weld flange temperatures before sealing with IAEA.
- If temperatures exceed limits outlined in Table 1 above, OPG suggest tri-seals to be applied (i.e., LMCV, FBOS, & Metallic). Monitor health seals during regular IAEA visits. OPG will also explore using mixed age modules.
- If the above commissioning DSC is excessively hot, then the DSC will need to be reverse loaded (see below, Reverse Loading). DSC temperatures will be controlled operationally – for example through the mixed age module loading.

Based on discussions, the IAEA have agreed to support the commissioning DSC test case to see if the actual temperatures are similar to the calculated temperatures or more similar to OPEX of DSC 0024. An Operating Memo is currently being prepared to provide the changes to documents required to operationalize the change. This will be completed prior to commissioning of the first DSC.

Reverse Loading

If the temperatures are higher than the limits required as discussed above, there will need to be a backout option to reverse load the DSC back to the IFB-B. A reverse loading plan is being developed to outline the steps required to reverse load a DSC loaded with 6-year cooled fuel. The plan will include lessons learned and OPEX from the 2012 event documented in Station Condition Record N-2012-00289, "*Supertool Malfunctions While Loading DSC*". This DSC had to be emptied. The reverse loading plan will be issued before the loading of any DSCs containing minimum 6-year cooled fuel. OPG will provide the reverse loading plan to CNSC staff by March 22, 2024.

Impact of the Storage of Minimum 6-Year Cooled Fuel on OPG Governance, Programs and Processes

The table below provides the list of OPG governance, programs and processes that form the licensing basis for PWMF's Operating Performance and identifies the impact of the storage of minimum 6-year cooled fuel on these programs. Identified changes in new revisions of licensing basis documents will be submitted by written notification to the CNSC per the requirements of the PWMF LCH LC G2.

Impact of the Storage of Minimum 6-Year Cooled Fuel on PWMF's Operating Performance Related Licensing Basis Documents

OPG Document Title	OPG Document Number	Impact from the Storage of Minimum 6-Year Cooled Fuel
Application for Renewal of Pickering Waste Management Facility Operating Licence	92896-CORR-00531-01031	No Change

Additional Information to Support the Application for Renewal of Pickering Waste Management Facility Operating Licence	92896-CORR-00531-01075	No Change
Nuclear Waste Management	W-PROG-WM-0001	No Change
Operating Policies and Principles, Pickering Waste Management Facility	92896-OPP-01911.1-00001	To be updated by March 15, 2024.
Pickering Waste Management Facility – Safety Report	92896-SR-01320-10002	No Change*

*An addendum to 92896-SR-01320-10002 will be provided to CNSC staff by September 30, 2024, after the trialing of the initial DSCs containing minimum 6-year cooled fuel.

Impact of the Storage of Minimum 6-Year Cooled Fuel on OPG Governance, Programs and Processes

The table below provides the list of OPG governance, programs and processes that form the licensing basis for PWMF's Operating Performance and identifies the impact of the storage of minimum 6-year cooled fuel on these programs.

Impact of the Storage of Minimum 6-Year Cooled Fuel on PWMF's Operating Performance Related Licensing Basis Documents

OPG Document Title	OPG Document Number	Impact from the Storage of Minimum 6-Year Cooled Fuel
Conduct of Regulatory Affairs	N-PROG-RA-0002	No Change
Performance Improvement	N-PROG-RA-0003	No Change
Preliminary Event Notification	N-PROC-RA-0020	No Change
Operating Policies and Principles, Pickering Waste Management Facility	92896-OPP-01911.1-00001	To be updated by March 15, 2024, prior to commissioning of the first DSC with minimum 6-year cooled fuel.

The following documents related to operations (but not included in the licensing basis) will also be updated prior to the commissioning of the first DSC containing minimum 6-year cooled fuel:

Document Number	Document Title
92896-MAN-79171-00001	IFB Loading
W-WOEP-79171-000010	Dry Storage Container Reverse Loading
W-PROC-WM-0082	Eastern Waste Acceptance Criteria for Used Fuel Dry Storage Containers
92896-OP-35540-00001	Pickering Waste Management Facility (PWMF) General
92896-OP-79171-00001	Pickering Waste Management Facility Operating Procedure Dry Storage Container Processing
92896-SR-01320-10002	Pickering Waste Management Facility – Safety Report
92896-OP-35570-00001	International Atomic Energy Agency Safeguards (*If required based on commissioning results)
92896-OP-79171-00003	DSC Loading PNGS 058 Irradiated Fuel Bay (IFB-B)
92896-OP-79171-00004	DSC Loading Auxiliary Irradiated Fuel Bay

LC 3.2 Reporting Requirements

Licence Condition 3.2 states "*the licensee shall implement and maintain a program for reporting to the Commission or a person authorized by the Commission*" and the details in the PWMF Licence Conditions Handbook (LCH) outline the regulatory requirements. The information provided in the last PWMF licence application is still valid.

List of Reporting Related Regulatory Requirements

Licensing Basis Document Title	Document Number	Impact from Storage of Minimum 6-Year Cooled Fuel
Public Information and Disclosure	CNSC REGDOC-3.2.1 (2018)	Continued compliance, no impact.
Reporting Requirements, Volume I: Non-Power Reactor Class I Nuclear Facilities and Uranium Mines and Mills	CNSC REGDOC-3.1.2 (2018)	Continued compliance, no impact.

Quarterly and Annual Operational Reporting

Quarterly and Annual operational reporting will continue as currently conducted and will account for the DSCs containing minimum 6-year cooled fuel.

LC 4.1 Safety Analysis Program

Licence Condition 4.1 states "*the licensee shall implement and maintain a safety analysis program*" and the details in the PWMF Licence Conditions Handbook (LCH) outline the regulatory requirements. The information provided in the last PWMF licence application is still valid.

Safety Assessment

As concluded in the safety analysis provided in Enclosure 2 of Reference [2-1]: the safety assessment demonstrates compliance with the radiation safety requirements during normal operation of the PWMF when SB3 is in service. With the addition of the 100 DSCs containing minimum 6- year cooled fuel, the annual public dose estimates have increased compared to that of the existing PWMF configuration. The maximum annual dose to individual member of the public with the addition of these 100 DSCs is still a small percentage of the 1 mSv limit. Due to the specialized array of storing the DSCs containing minimum 6-year cooled fuel, the target dose rate to the public of 0.5mSv will also be met. With respect to malfunction and accident scenarios, the estimated bounding doses to members of the public are less than the 1 mSv acceptance criterion. The dose to workers following a postulated accident scenario is found to be much less than the 50 mSv limit. It is concluded that the dose consequences to workers and members of the public as a result of credible postulated malfunction / accident scenarios meet all acceptance criteria.

Enclosures 2 and 3 of Reference [2-1] were previously provided to CNSC staff in 2020 (Enclosure 3 and 2 of Reference [2-2] respectively) before it was determined that a Licence Amendment would be required to store minimum 6-year cooled fuel. OPG will undertake a code applicability report of the Safety Analysis by March 15, 2024. 92896-MDR-79171-00001, "*Modification Design Requirements for Loading, Transferring, Processing and Storing Minimum 6-year-old Fuel at NSSP*" (Enclosure 2 of this submission) specifies the design requirements to ensure the impact of loading, transferring, processing, and storing minimum 6-year cooled fuel have been assessed for DSCs with respect to the structural integrity, shielding and containment functions of the DSC under normal and accident conditions. 00104-CORR-79171-0139942, "*Additional Information Concerning Thermal Gradients Pertaining to Dry Storage Containers (DSCs)*" (Enclosure 4 of Reference [2-1]) contains information (previously requested by the CNSC) regarding the trialing of a single DSC containing 6-year cooled fuel in 1998.

List of Safety Analysis Program Related Regulatory Requirements

Licensing Basis Document Title	Document Number	Impact from the Storage of Minimum 6-Year Cooled Fuel
General principles for the management of radioactive waste and irradiated fuel	CSA N292.0 (2014)	Minimum 6-year cooled fuel safety assessments were conducted in compliance with applicable requirements
Interim dry storage of irradiated fuel	CSA N292.2 (2013)	Minimum 6-year cooled fuel safety assessments were conducted in compliance with applicable requirements
Management of low- and intermediate-level radioactive waste	CSA N292.3 (2014)	Minimum 6-year cooled fuel safety assessments were conducted in compliance with applicable requirements
Quality assurance of analytical, scientific, and design computer programs	CSA N286.7 (2016)	Minimum 6-year cooled fuel safety assessments were conducted in compliance with applicable requirements

Impact of the Storage of Minimum 6-Year Cooled Fuel on OPG Governance, Programs and Processes

The table below provides the list of OPG governance, programs and processes that form the licensing basis for PWMF's Safety Analysis program and identifies the impact of storing minimum 6-year cooled fuel on these programs and processes.

Impact of the Storage of Minimum 6-year Cooled Fuel on PWMF's Safety Analysis Licensing Basis Documents

OPG Safety Analysis Licensing Basis Document Title	OPG Document Number	Impact from the Storage of Minimum 6-Year Cooled Fuel
Pickering Waste Management Facility – Safety Report	92896-SR-01320-10002	An addendum will be provided to CNSC staff by September 30, 2024, after the trialing of the initial DSCs containing minimum 6-year cooled fuel.

LC 5.1 Design Program

Licence Condition 5.1 states "*the licensee shall implement and maintain a design program*" and the details in the PWMF Licence Conditions Handbook (LCH) outline the regulatory requirements. The information provided in the last PWMF licence application is still valid.

List of Design Program Related Regulatory Requirements

Licensing Basis Document Title	Document Number	Impact from the Storage of Minimum 6-Year Cooled Fuel
Fire protection for facilities that process, handle, or store nuclear substances	CSA N393 (2013)	No impact from the storage of minimum 6-year cooled fuel.
National Building Code of Canada (2020)	NRC	The PWMF SB's design complies with the requirements in this national code.
National Fire Code of Canada (2020)	NRC	The PWMF SB's design complies with the requirements in this national code.

Facility and DSC Design

The storage of minimum 6-year cooled fuel will not require any change to the facility design. The DSC currently used for minimum 10-year cooled fuel will also be used for the storage of minimum 6-year cooled fuel.

Impact of the Storage of Minimum 6-year Cooled Fuel on OPG Governance, Programs and Processes

The table below provides the list of OPG governance, programs and processes that form the licensing basis for PWMF's Design Program and identifies the impact of the storage of minimum 6-year cooled fuel on these programs and processes.

Impact of the Storage of Minimum 6-year Cooled Fuel on PWMF's Design Program Related Licensing Basis Documents

OPG Physical Design Licensing Basis Document Title	OPG Document Number	Impact from Storage of Minimum 6-Year Cooled Fuel
Conduct of Engineering	N-STD-MP-0028	No Change
Configuration Management	N-STD-MP-0027	No Change
Design Management	N-PROG-MP-0009	No Change
Engineering Change Control	N-PROG-MP-0001	No Change

LC 5.2 Pressure Boundary

Licence Condition 5.2 states "*the licensee shall implement and maintain a training program*" and the details in the PWMF Licence Conditions Handbook (LCH) outline the regulatory requirements. The information provided in the last PWMF licence application is still valid.

List of Pressure Boundary Program Related Regulatory Requirements

Licensing Basis Document Title	Document Number	Impact from the Storage of Minimum 6-Year Cooled Fuel
Power Piping	ASME (2010)	No impact from the storage of minimum 6-year cooled fuel.
Boiler, pressure vessel, and pressure piping code	CSA B51 (2009 and Update No. 1)	No impact from the storage of minimum 6-year cooled fuel.
General requirements for pressure-retaining systems and components in CANDU nuclear power plants	CSA N285.0 (2008 and Updates No. 1 and 2; and Annex N of N285.0-12 and Update No. 1)	No impact from the storage of minimum 6-year cooled fuel.

Impact of the Storage of Minimum 6-year Cooled Fuel on OPG Governance, Programs and Processes

The table below provides the list of OPG governance, programs and processes that form the licensing basis for PWMF's Design Program and identifies the impact of the storage of minimum 6-year cooled fuel on these programs and processes.

Impact of the Storage of Minimum 6-Year Cooled Fuel on PWMF's Design Program Related Licensing Basis Documents

OPG Physical Design Licensing Basis Document Title	OPG Document Number	Impact from Storage of Minimum 6-Year Cooled Fuel
Index to OPG Pressure Boundary Program Elements	N-LIST-00531-10003	No Change
Pressure Boundary Program Manual	N-MAN-01913.11-10000	No Change
Authorized Inspection Agency Service Agreement	N-CORR-00531-20012	No Change
Design Registration	N-PROC-MP-0082	No Change
Pressure Boundary	N-PROC-MP-0004	No Change
System and Item Classification	N-PROC-MP-0040	No Change

LC 6.1 Fitness for Service Program

Licence Condition 6.1 states "*the licensee shall implement and maintain a fitness for service program*" and the details in the PWMF Licence Conditions Handbook (LCH) outline the regulatory requirements. The information provided in the last PWMF licence application remains valid.

List of Fitness for Service Program Related Regulatory Requirements

Licensing Basis Document Title	Document Number	Impact from Storage of Minimum 6-Year Cooled Fuel
Aging Management	CNSC REGDOC-2.6.3 (2014)	The storage of minimum 6-year cooled fuel will be incorporated into the aging management program as applicable as part of the ECC process.

Impact of the Storage of Minimum 6-Year Cooled Fuel on OPG Governance, Programs and Processes

The table below provides the list of OPG governance, programs and processes that form the licensing basis for PWMF's Fitness for Service and identifies the impact of the storage of minimum 6-year cooled fuel on these programs and processes.

Impact of the Storage of Minimum 6-Year Cooled Fuel on PWMF's Aging Management Program Related Licensing Basis Documents

OPG Fitness for Service Licensing Basis Document Title	OPG Document Number	Impact from Storage of Minimum 6-Year Cooled Fuel
Conduct of Engineering	N-STD-MP-0028	No Change
Design Management	N-PROG-MP-0009	No Change
Equipment Reliability	N-PROG-MA-0026	No Change
Integrated Aging Management	N-PROG-MP-0008	No Change
Nuclear Waste Management	W-PROG-WM-0001	No Change
Ontario Power Generation Dry Storage Container – Base (Underside) Inspection Plan	00104-PLAN-79171-00002	No Change
Used Fuel Dry Storage Container Aging Management Plan	00104-PLAN-79171-00001	No Change

OPG will be undertaking a condition assessment report using the indicators from the initial trialing of the two to four DSCs to assess any degradation mechanism and any impact on the aging/service life while storing minimum 6-year cooled fuel. This report is expected to be completed by December 2024 and any new findings from this condition assessment report will be reviewed and incorporated into the DSC aging management plan accordingly.

LC 7.1 Radiation Protection

Licence Condition 7.1 states "*the licensee shall implement and maintain a radiation program, which includes a set of action levels. When the licensee becomes aware that an action level has been reached, the licensee shall notify the Commission within seven days"* and the details in the PWMF Licence Conditions Handbook (LCH) outline the regulatory requirements. The information provided in the last PWMF licence application is still valid.

As per OPG's N-PROG-RA-0013, "*Radiation Protection*", the overriding objective of the Radiation Protection (RP) program at OPG is the control of occupational and public exposure to radiation. For the purposes of controlling radiation doses to workers and the public, this program has five implementing objectives:

- Keeping individual radiation doses below regulatory limits
- Avoiding unplanned radiation exposures
- Keeping individual risk from lifetime radiation exposure to an acceptable level
- Keeping collective radiation doses ALARA, social and economic factors taken into account
- Keeping public exposure to radiation well within regulatory limits.

Higher Dose Rates

Higher dose rates from the minimum 6-year cooled fuel DSCs directly impacts workers and equipment that interface with the DSC. It has been analyzed that the anticipated dose rates would be approximately 2.5 times higher in comparison to the storage of 10-year cooled fuel. This is manageable with a different Radiation Exposure Permit (REP) to address worker safety; and no meaningful impact on OPG equipment. Dose rates will be managed with the As Low as Reasonably Achievable (ALARA) principles associated with an updated REP.

New REPs for workers interfacing with the minimum 6-year cooled fuel will be developed and implemented prior to commissioning of any DSCs containing minimum 6-year cooled fuel.

OPG will perform detailed measurements during initial placement of the loaded DSCs containing minimum 6-year cooled fuel to compare against estimated values using various types of gamma meters (i.e., energy compensated Geiger Mueller, Ion chamber) at multiple locations and distances from the DSCs. An ‘as found’ dose-rate criteria of approximately 150 μSv/h at near contact and approximately 80 μSv/h at 1 m will be considered in line with estimated values, modelled uncertainty and nominal variance in field accuracy of the various instruments used. If ‘as found’ gamma radiation readings are appreciably above estimated values, further evaluation of the propagated impact on subsequent storage will be taken (i.e., impact on storage strategy of higher than estimated DSCs to bounding safety case analysis). Short term/immediate actions will include unique identification of minimum 6-year cooled fuel DSCs and radiation protection controls to ensure workers dose are ALARA (e.g. place affected DSCs in low traffic areas, utilize surrounding low dose rate DSCs to act as shielding). OPG will provide the results of the confirmatory dose rate surveys to CNSC staff immediately after the initial commissioning loading of DSCs.

The bounding case of storing all 100 DSCs containing minimum 6-year cooled fuel in PWMF SB 3 in the locations assessed is acceptable. This is the worst-case ratio of 100/380 (where 480 DSCs are in storage in PWMF SB3). However, this is highly unlikely.

OPG confirms that the planned pattern shown in Figures 7 and 8 of Enclosure 2 of Reference [2-1] remain valid, and that the neither the figures or assessed pattern for storage has been reassessed or updated the past three years. The pattern shown still bounds the expected conditions for storage at the expected time of loading the DSCs containing the minimum 6-year cooled fuel. OPG will be performing a dose assessment based on the measured dose rates and/or doses received to workers from DSC processing activities immediately after the loading of two to four trial DSCs.

Estimated Public Dose

Estimated public doses have been analyzed in Enclosure 2 of Reference [2-1] (section 5.3.3) and in Enclosure 3 of Reference [2-1] (section 4.3.2). Both analyses assess that the dose to public, as a result of the storage of minimum 6-year cooled fuel in SB3, remains far below regulatory limits.

Based on previous correspondence with the CNSC, and reaffirmed in this application, dose rates will be measured during the initial placement of minimum 6-year cooled fuel and actions will be taken are taken prior to the dose rate criterion being exceeded.

Dose Rates and Temperature Impact on the Public and Environment

Analysis has been conducted on the indirect impact that dose rates and temperatures would have on OPG equipment and the public/environment. The transfer of the DSC from IFB-B to the processing building, then to interim storage in SB1 and lastly to its final destination in SB3. This increase in dose and temperature has been analyzed to be within the regulatory limits for the public and environment (including all Action Levels stated in the PWMF LCH).

The existing TLDs around PWMF Phase I and Phase II will measure the dose rates, which are reported quarterly to the CNSC in the facility Operations Report. Monitoring of these results will confirm the impact on the regulatory dose rates. However, as SB3 is a shielded building, it is not anticipated to be a concern.

Thermal Analysis for PWMF SB3 storing minimum 6-year cooled fuel has been completed during design. DSCs containing minimum 6-year cooled fuel will be placed in the middle of SB3. An increase in dose and temperature has been analyzed to be within the regulatory limits to the public and environment. Temperature monitoring inside SB3 will be in place prior to the commissioning of any DSCs containing minimum 6-year cooled fuel.

List of Radiation Protection Related Regulatory Requirements

Licensing Basis Document Title	Document Number	Impact from the Storage of Minimum 6-year Cooled Fuel
Radiation Protection Regulations	SOR/2000-203	Continued compliance as documented in Attachment 1

Impact of the Storage of Minimum 6-Year Cooled Fuel on PWMF’s Radiation Protection Program Related Licensing Basis Documents

The table below provides the list of OPG governance, programs and processes that form the licensing basis for PWMF’s Radiation Protection and identifies the impact of the storge of minimum 6-year cooled fuel on these programs.

Impact from the Storage of Minimum 6-year Cooled Fuel on PWMF's Radiation Protection and ALARA Licensing Basis Documents

OPG Radiation Protection Licensing Basis Document Title	OPG Document Number	Impact from the Storage of Minimum 6-year Cooled Fuel
Occupational Radiation Protection Action Levels for Nuclear Waste Management Facilities	N-REP-03420-10011	No Change
Radiation Protection	N-PROG-RA-0013	No Change

LC 8.1 Conventional Health and Safety

Licence Condition 8.1 states "*the licensee shall implement and maintain a conventional health and safety program"* and the details in the PWMF Licence Conditions Handbook (LCH) outline the regulatory requirements. The information provided in the last PWMF licence application is still valid.

Regulatory Requirements Related to Conventional Health and Safety

Licensing Basis Document Title	Document Number	Impact from the Storage of Minimum 6-year Cooled Fuel
General Nuclear Safety and Control Regulations	SOR/2000-202	Continued compliance as documented in Attachment 1

Ensuring Conventional Safety Performance

The foundation of OPG's Health and Safety Management System is OPG-POL-0001, "*Employee Health and Safety Policy*" which describes the approach and commitments to conventional health and safety for the organization, and the requirements and accountabilities of all employees.

OPG's program document OPG-PROG-0005, "*Environment Health and Safety Managed Systems*" governs the design and execution of OPG's Health and Safety Managed Systems in accordance with OPG-POL-0001. The Health and Safety Managed System program and supporting governing documents establish process requirements that protect employees by ensuring they are working safely in a healthy and injury-free workplace. It also outlines the responsibilities of various levels in the organization to ensure activities are performed to meet the requirements of OPG's Health and Safety Policy.

Impact from the Storage of Minimum 6-year Cooled Fuel on OPG Governance, Programs and Processes

The table below provides the list of OPG governance, programs and processes that form the licensing basis for PWMF's Conventional Safety program and identifies the impact of the storage of minimum 6-year cooled fuel on these programs and processes.

Impact from the Storage of Minimum 6-year Cooled Fuel on PWMF's Conventional Safety Program Licensing Basis Documents

OPG Conventional Safety Licensing Basis Document Title	OPG Document Number	Impact from the Storage of Minimum 6-year Cooled Fuel
Employee Health and Safety Policy	OPG-POL-0001	No Change
Health and Safety Management System Program	OPG-PROG-0010	No Change

LC 9.1 Environmental Protection

Licence Condition 9.1 states "*the licensee shall implement and maintain an environmental protection program, which includes a set of action levels. When the licensee becomes aware that an action level has been reached, the licensee shall notify the Commission within seven days"* and the details in the PWMF Licence Conditions Handbook (LCH) outline the regulatory requirements. The information provided in the last PWMF licence application is still valid.

List of Environmental Protection Related Regulatory Requirements

Licensing Basis Document Title	Document Number	Impact from the Storage of Minimum 6-year Cooled Fuel
Environmental Protection: Environmental Principles, Assessments and Protection Measures	REGDOC-2.9.1, Section 4.6 (2016)	Environmental-related assessments were conducted in accordance with requirements
Environment management of nuclear facilities: Common requirements of the CSA N288 series of Standards	CSA N288.0 (2022)	Environmental-related assessments were conducted in accordance with requirements
Guidelines for calculating derived release limits for radioactive material in airborne and liquid effluents for normal operation of nuclear facilities	CSA N288.1 (2014 R2019)	Environmental-related assessments were conducted in accordance with requirements

Performance Testing of Nuclear Air-Cleaning Systems at Nuclear Facilities	CSA N288.3.4 (2013 R2018)	Environmental-related assessments were conducted in accordance with requirements
Environmental monitoring program at class I nuclear facilities and uranium mines and mills	CSA N288.4 (2010 R2015)	Environmental-related assessments were conducted in accordance with requirements
Effluent monitoring programs at class I nuclear facilities and uranium mines and mills	CSA N288.5 (2022)	Environmental-related assessments were conducted in accordance with requirements
Environmental risk assessments at class I nuclear facilities and uranium mines and mills	CSA N288.6 (2012 R2017)	Environmental-related assessments were conducted in accordance with requirements
Groundwater protection programs at Class I nuclear facilities and uranium mines and mills.	CSA N288.7 (2015 R2020)	Environmental-related assessments were conducted in accordance with requirements
Establishing and Implementing Action Levels for Releases to the Environment from Nuclear Facilities	CSA N288.8 (2017 R2022)	Environmental-related assessments were conducted in accordance with requirements

Effluent and Emissions Control (Releases)

OPG is committed to complying with the requirements of the CSA Standard N288 series documents, as required in the PWMF LCH. The licensee shall control radiological releases to ALARA, thereby minimizing dose to the public resulting from PWMF operation.

The PWMF adheres to approved Derived Release Limits (DRLs) under PNGS, which are defined in CSA Standard N288.1 as the release rate that would cause an individual of the most highly exposed group to receive and be committed to a dose equal to the regulatory annual dose limit, due to release of a given radionuclide to air or surface water during normal operation of a nuclear facility over the period of a calendar year.

Because radiological releases are very small in comparison with the Derived Release Limits (DRLs) and Action Levels, lower Internal Investigation Levels (IILs) are used to demonstrate and maintain adherence to the ALARA principle. There will be no changes to the DRLs, Action Levels or IILs as a result of the storage of minimum 6-year cooled fuel. Consistent with current performance, the cumulative public dose resulting from the storage of the minimum 6-year cooled fuel will remain well below 1% of the regulatory public dose limit of 1,000 μSv per year.

Under normal operating conditions, no airborne emissions are expected from loaded DSCs during transfer from the Fueling Facility Auxiliary Areas to the PWMF. Airborne releases are also unlikely to arise under normal operating conditions during storage of seal welded DSCs. There is a small potential for airborne emissions resulting from DSC processing operations such as welding and vacuum drying. The DSC processing building has a dedicated active ventilation system with HEPA filtration. The active ventilation exhaust from the DSC Processing Building has historically been monitored for radioactive particulates for confirmation purposes. The historical monitoring confirms that particulate emissions are negligible.

Releases of HTO, Kr-85, and C-14 from the DSCs are not expected, but a conservative scenario has been assessed to demonstrate that dose from releases would be very low. Specific monitoring for HTO, Kr-95 and C-14 is not required per N-STD-OP-0031, "*Monitoring of Nuclear and Hazardous Substances in Effluents*".

Environmental Management System (EMS)

OPG's OPG-POL-0021, "*Environmental Policy*" requires that OPG maintain an Environmental Management System (EMS) consistent with the ISO 14001, "*Environmental Management System Standard*".

Operation of the PWMF will continue to be in accordance with OPG's EMS as described in OPG-PROG-0005, "*Environment Health and Safety Managed Systems*" and OPG-POL-0021. The EMS provides specific direction on how the Environmental Policy is implemented while meeting the expectations of OPG-POL-0032, "*Safe Operations Policy*", N-POL-0001, "*Nuclear Safety & Security Policy"*, and N-CHAR-AS-0002, "*Nuclear Management System*".

Continued Validity of Prior Submissions to the CNSC/Licensing Documents

Enclosure 1 of this submission contains an assessment that reviewed the following current

licensing documents: Environmental Assessments (EAs):

- Pickering Waste Management Facility Phase II Final Environmental Assessment Study Report. December 2003. 92896-REP-07701-00002
- Refurbishment and Continued Operation of Pickering B Nuclear Generating Station Environmental Assessment. December 2007. NK30-REP-07701-00002

Environmental Risk Assessment (ERA) and Predictive Effects Assessment (PEA):

- ERA for Pickering Nuclear. Feb 2018. P-REP-07701-00001 R001
- PEA for Pickering Nuclear Safe Storage. April 2017. P-REP-07701-00002 R000

Operating Licences and Handbooks:

- Nuclear Power Reactor Operating Licence. Pickering Nuclear Generating Station. PROL 48.00/2028.
- Pickering Nuclear Generating Station Nuclear Power Reactor. Licence Conditions Handbook. LCH-PR-48.00/2028-R000.
- Waste Facility Operating Licence. Pickering Waste Management Facility. WFOL-W4-350.0/2028.
- Pickering Waste Management Facility. Licence Conditions Handbook. LCH-W4-350.00/2028.

As a result, OPG concluded that a stand-alone environmental submission to CNSC is not required since loading, transporting, and storage of minimum 6-year cooled fuel is considered to be within the scope of the relevant project EAs and falls within the conditions of the

Pickering Nuclear and PWMF Waste Operating Licences.

Impact from the Storage of Minimum 6-year Cooled Fuel on OPG Governance, Programs and Processes

The table below provides the list of OPG governance, programs and processes that form the licensing basis for PWMF's Environmental Protection and identifies the impact of the storage of minimum 6-year cooled fuel on these programs and processes.

Impact from the Storage of Minimum 6-year Cooled Fuel on PWMF's Environmental Protection Licensing Basis Documents

OPG Environmental Protection Licensing Basis Document Title	OPG Document Number	Impact from the Storage of Minimum 6-year Cooled Fuel
Environment Health and Safety Managed Systems	OPG-PROG-0005	No Change
Environment Policy	OPG-POL-0021	No Change
Management of the Environmental Monitoring Program	N-PROC-OP-0025	No Change
Monitoring of Nuclear and Hazardous Substances in Effluents	N-STD-OP-0031	No Change
Environmental Risk Assessment Report for Pickering Nuclear	P-REP-07701-00001	No Change
Derived Release Limits and Environmental Action Levels for Pickering Nuclear	P-REP-03482-00006	No Change

LC 9.2 Environmental Assessment Follow-Up Program

Licence Condition 9.2 states "*the licensee shall implement an environmental assessment follow-up plan"* and the details in the PWMF Licence Conditions Handbook (LCH) outline the regulatory requirements. The information provided in the last PWMF licence application is still valid.

Enclosure 1 of this submission contains an assessment of the continued validity of the PWMF Phase II Site Environmental Assessment (EA) (December 2003) with the storage of minimum 6-year cooled fuel. As a result, the EA Follow-Up Plan also remains valid and will continue to be conducted as originally committed for SB3.

Impact from the Storage of Minimum 6-year Cooled Fuel on OPG Governance, Programs and Processes

The table below provides the list of OPG governance, programs and processes that form the licensing basis for PWMF's Environmental Assessment Follow-Up Plan and identifies the impact of the storage of minimum 6-year cooled fuel on these programs and processes.

Impact from the Storage of Minimum 6-year Cooled Fuel on PWMF's Environmental Assessment Follow-Up Plan Licensing Basis Documents

OPG Environmental Protection Licensing Basis Document Title	OPG Document Number	Impact from the Storage of Minimum 6-year Cooled Fuel
Pickering Waste Management Facility Phase II – Environmental Assessment Follow-Up Plan	92896-REP-07701.8-00001	No Change

LC 10.1 Emergency Preparedness Program

Licence Condition 10.1 states "*the licensee shall implement an emergency preparedness program"* and the details in the PWMF Licence Conditions Handbook (LCH) outline the regulatory requirements. The information provided in the last PWMF licence application is still valid.

List of Emergency Management Related Regulatory Requirements

Licensing Basis Document Title	Document Number	Impact from the Storage of Minimum 6-year Cooled Fuel
Nuclear Emergency Preparedness and Response, Version 2	CNSC REGDOC-2.10.1 (2017)	No change

Nuclear Emergency Preparedness and Response

OPG's Emergency Preparedness program N-PROG-RA-0001, "*Consolidated Nuclear Emergency Plan*", requires OPG staff to implement and maintain its emergency response capability to protect the public, employees, and the environment in the event of a nuclear emergency."

Impact of the Storage of Minimum 6-Year Fuel on OPG Governance, Programs and Processes

The table below provides the list of OPG governance, programs and processes that form the licensing basis for PWMF's Emergency Management and identifies the impact of the storage of minimum 6-year cooled fuel on these programs and processes.

Impact from the Storage of Minimum 6-year Cooled Fuel on PWMF's Emergency Management Licensing Basis Documents

OPG Emergency Management and Fire Protection Licensing Basis Document Title	OPG Document Number	Impact
Radioactive Materials Transportation Emergency Response Plan	N-STD-RA-0036	No Change
Consolidated Nuclear Emergency Plan	N-PROG-RA-0001	No Change

LC 10.2 Fire Protection Program

Licence Condition 10.2 states "*the licensee shall implement a fire protection program"* and the details in the PWMF Licence Conditions Handbook (LCH) outline the regulatory requirements. The information provided in the last PWMF licence application is still valid.

List of Fire Protection Related Regulatory Requirements

Licensing Basis Document Title	Document Number	Impact from the Storage of Minimum 6-year Cooled Fuel
Fire protection for facilities that process, handle, or store nuclear substances	CSA N393-13 (2013)	No Change
National Building Code of Canada (2020)	NRC	No Change
National Fire Code of Canada (2020)	NRC	No Change

Fire Emergency Preparedness and Response

OPG's Fire Protection program, N-PROG-RA-0012, "*Fire Protection"* establishes provisions to prevent, mitigate and respond to fires such that fire risk to OPG Nuclear workers, public, environment, nuclear physical assets, and power generation, is acceptably low and controlled. There will be no changes to N-PROG-RA-0012 as a result of the storage of minimum 6-year cooled fuel.

Impact of the Storage of Minimum 6-Year Fuel on OPG Governance, Programs and Processes

The table below provides the list of OPG governance, programs and processes that form the licensing basis for PWMF's Fire Protection and identifies the impact of the storage of minimum 6-year cooled fuel on these programs and processes.

Impact from the Storage of Minimum 6-year Cooled Fuel on PWMF's Fire Protection Licensing Basis Documents

OPG Emergency Management and Fire Protection Licensing Basis Document Title	OPG Document Number	Impact from the Storage of Minimum 6-year Cooled Fuel
Fire Protection	N-PROG-RA-0012	No Change

LC 11.1 Waste Management Program

Licence Condition 11.1 states "*the licensee shall implement a waste management program"* and the details in the PWMF Licence Conditions Handbook (LCH) outline the regulatory requirements. The information provided in the last PWMF licence application is still valid.

List of Waste Management Related Regulatory Requirements

Licensing Basis Document Title	Document Number	Impact from the Storage of Minimum 6-year Cooled Fuel
General principles for the management of radioactive waste and irradiated fuel	CSA N292.0 (2019)	The storage of minimum 6- year cooled fuel complies with the requirements in this CSA Standard.
Interim dry storage of irradiated fuel	CSA N292.2 (2013)	The storage of minimum 6- year cooled fuel complies with the requirements in this CSA Standard.
Management of low and intermediate-level radioactive waste	CSA N292.3 (2014)	The storage of minimum 6- year cooled fuel complies with the requirements in this CSA Standard.

Impact of the Storage of Minimum 6-year Cooled Fuel on OPG Governance, Programs and Processes

The table below provides the list of OPG governance, programs and processes that form the licensing basis for PWMF's Waste Management program and identifies the impact of the storage of minimum 6-year cooled fuel on these programs and processes.

Impact of the Storage of Minimum 6-year Cooled Fuel on PWMF's Waste Management Licensing Basis Documents

OPG Waste Management Licensing Basis Document Title	OPG Document Number	Impact from the Storage of Minimum 6-Year Cooled Fuel
Segregation and Handling of Radioactive Wastes	N-PROC-RA-0017	No Change
Management of Waste and Other Environmentally Regulated Materials	OPG-STD-0156	No Change
Nuclear Waste Management	W-PROG-WM-0001	No Change
Radiation Protection	N-PROG-RA-0013	No Change

LC 11.2 Decommissioning Plan

Licence Condition 11.2 states "*the licensee shall maintain a decommissioning plan"* and the details in the PWMF Licence Conditions Handbook (LCH) outline the regulatory requirements. The information provided in the last PWMF licence application is still valid.

List of Decommissioning Related Regulatory Requirements

Licensing Basis Document Title	Document Number	Impact from the Storage of Minimum 6-year Cooled Fuel
Decommissioning of facilities containing nuclear substances	CSA N294-09 (2009)	The storage of minimum 6-year cooled fuel complies with the requirements in this CSA Standard.

Decommissioning of facilities containing nuclear substances	CSA N294-19 (2019)	The storage of minimum 6-year cooled fuel complies with the requirements in this CSA Standard.

Preliminary Decommissioning Plan

As the DSC used to store minimum 6-year cooled fuel remains the same, there is no requirement to update the Preliminary Decommissioning Plan (PDP). The current PWMF PDP does not stipulate the age of the fuel being stored within the DSC.

Impact of the Storage of Minimum 6-year Cooled Fuel on OPG Governance, Programs and Processes

The table below provides the list of OPG governance, programs and processes that form the licensing basis for PWMF's Decommissioning Plan and identifies the impact of the storage of minimum 6-year cooled fuel on these programs and processes.

Impact of the Storage of Minimum 6-year Cooled Fuel on PWMF's Decommissioning Licensing Basis Documents

OPG Waste Management Licensing Basis Document Title	OPG Document Number	Impact from the Storage of Minimum 6-year Cooled Fuel
Decommissioning Program	W-PROG-WM-0003	No Change
Preliminary Decommissioning Plan Pickering Waste Management Facility	92896-PLAN-00960-00001	No Change

LC 12.1 Security Program

Licence Condition 12.1 states "*the licensee shall implement and maintain a security program"* and the details in the PWMF Licence Conditions Handbook (LCH) outline the regulatory requirements. The information provided in the last PWMF licence application is still valid.

List of Security Related Regulatory Requirements

Licensing Basis Document Title	Document Number	Impact from the Storage of Minimum 6-year Cooled Fuel
Nuclear Security Regulations	SOR/2000-209	Compliance documented in Attachment 1
Fitness for Duty, Volume III: Nuclear Security Officer Medical, Physical, and Psychological Fitness	CNSC REGDOC-2.2.4 (2018)	Continued compliance.
High Security Facilities, Volume II: Criteria for Nuclear Security Systems and Devices	CNSC REGDOC-2.12.1 (2018)	Continued compliance.
Site Access Security Clearance	CNSC REGDOC- 2.12.2 (2013)	Continued compliance.

Facilities and Equipment

The storage of minimum 6-year cooled fuel will not require changes to security related facilities, equipment or staffing levels at PWMF.

Response Arrangements

The storage of minimum 6-year cooled fuel will not require changes to security response arrangements or processes.

Impact from the Storage of Minimum 6-year Cooled Fuel on OPG Governance, Programs and Processes

The table below provides the list of OPG governance, programs and processes that form the licensing basis for PWMF's Security program and identifies the Impact from the storage of minimum 6-year cooled fuel on these programs and processes.

Impact from the Storage of Minimum 6-year Cooled Fuel on PWMF's Security Program Licensing Basis Documents

OPG Security Licensing Basis Document Title	OPG Document Number	Impact from the Storage of Minimum 6-year Cooled Fuel
Pickering Waste Management Facility Phase II Security Report	92896-REP-08160-00001	No Change

Pickering Waste Management Facility Security Report Addendum	92896-REP-08160-00001 ADD 001	No Change
Transport Security Plan	TRAN-PLAN-03450- 10000	No Change
Nuclear Security	N-PROG-RA-0011	No Change
Cyber Security	N-PROC-RA-0135	No Change
Nuclear Waste Management Cyber Essential Assets	W-LIST-08161-00001	No Change

LC 12.2 Construction

Licence Condition 12.2 states "*the licensee shall not carry out the activities referred to in paragraph (iii) of Part IV of this licence that relate to completed construction activities in paragraph (iv) of Part IV of this licence until the submission of the proposed security arrangements and measures for the new building, or any potential modifications to the protected area that may be associated with this new building, that is acceptable to the Commission or a person authorized by the Commission"* and the details in the PWMF Licence Conditions Handbook (LCH) outline the regulatory requirements. The information provided in the last PWMF licence application is still valid.

No construction activities will be required as a result of the storage of minimum 6-year cooled fuel at PWMF.

LC 13.1 Safeguards Program

Licence Condition 13.1 states "*the licensee shall implement and maintain a safeguards program"* and the details in the PWMF Licence Conditions Handbook (LCH) outline the regulatory requirements. The information provided in the last PWMF licence application is still valid.

List of Safeguards and Non-Proliferation Related Regulatory Requirements

Licensing Basis Document Title	Document Number	Impact from the Storage of Minimum 6-year Cooled Fuel
Safeguards and Nuclear Material Accountancy	CNSC REGDOC-2.13.1 (2018)	Continued compliance

Nuclear Material Accountancy and Control

All reports and information necessary for safeguards implementation and compliance will continue to be provided to the IAEA and CNSC on a timely basis.

Access and Assistance to the IAEA

Canadian facilities are selected at random by the IAEA for physical inspections to confirm compliance with international non-proliferation requirements. The storage of minimum 6-year cooled fuel will have no impact on IAEA inspections or access to IAEA equipment.

Safeguards Equipment, Containment and Surveillance

The storage of minimum 6-year cooled fuel may have some impact on existing IAEA safeguards surveillance monitoring equipment (with respect to temperatures and sealing processes). This is discussed in section LC 3.1 Operating Performance. Analysis in this area continues and OPG continues to work with both the IAEA and CNSC to reach an agreeable outcome.

NuFlash

NuFlash is a system used for tracking nuclear fuel location and storage history. Currently, NuFlash does not allow the preparation of DSC packages for minimum 6-year cooled fuel. The changes required to update the NuFlash database to allow for 100 DSCs to be processed with 6-year to 10-year old fuel will be completed prior to the commissioning of the first DSC containing minimum 6-year cooled fuel.

Impact from the Storage of Minimum 6-year Cooled Fuel on OPG Governance, Programs and Processes

The table below provides the list of OPG governance, programs and processes that form the licensing basis for PWMF's Safeguards program and identifies the impact from the storage of minimum 6-year cooled fuel on these programs and processes.

Impact from the Storage of Minimum 6-year Cooled Fuel on PWMF's Safeguards Program Licensing Basis Documents

OPG Safeguards and Non- Proliferation Licensing Basis Document Title	OPG Document Number	Impact from the Storage of Minimum 6-year Cooled Fuel
Nuclear Safeguards	N-PROG-RA-0015	No Change
Nuclear Safeguards Implementation	N-STD-RA-0024	No Change

LC 14.1 Packaging and Transport Program

Licence Condition 14.1 states "*the licensee shall maintain a packaging and transport program"* and the details in the PWMF Licence Conditions Handbook (LCH) outline the regulatory requirements. The information provided in the last PWMF licence application is still valid.

Impact from the Storage of Minimum 6-year Cooled Fuel on OPG Governance, Programs and Processes

The table below provides the list of OPG governance, programs and processes that form the licensing basis for PWMF's Packaging and Transport program and identifies the impact of the storage of minimum 6-year cooled fuel on these programs and processes.

Impact from the Storage of Minimum 6-year Cooled Fuel on PWMF's Packaging and Transport Licensing Basis Documents

OPG Transportation and Packaging Licensing Basis Document Title	OPG Document Number	Impact from the Storage of Minimum 6-year Cooled Fuel
Radioactive Material Transportation	W-PROG-WM-0002	No Change
Radioactive Materials Transportation Emergency Response Plan	N-STD-RA-0036	No Change
Radiation Protection	N-PROG-RA-0013	No Change

Section 3: Other Matters of Regulatory Interest

Public Information and Engagement

OPG believes in timely open and transparent communication to maintain positive and supportive relationships and confidence of key stakeholders. OPG's Corporate Relations and Communications organization adheres to the principles and process for external communications as governed by the nuclear standard N-STD-AS -0013, "*Nuclear Public Information and Disclosure*".

List of Public Information and Disclosure Related Regulatory Requirements

Licensing Basis Document Title	Document Number	Impact from the Storage of Minimum 6-year Cooled Fuel
Public Information and Disclosure	CNSC REGDOC-3.2.1 (2018)	Continued compliance

Impact from the Storage of Minimum 6-year Cooled Fuel on OPG Governance, Programs and Processes

The table below provides the list of OPG governance, programs and processes that form the licensing basis for PWMF's Public Information and Disclosure program and identifies the impact of the storage of minimum 6-year cooled fuel on these programs and processes.

Impact from the Storage of Minimum 6-year Cooled Fuel on PWMF's Public Information and Disclosure Licensing Basis Documents

OPG Transportation and Packaging Licensing Basis Document Title	OPG Document Number	Impact from the Storage of Minimum 6-year Cooled Fuel
Nuclear Public Information Disclosure	N-STD-AS-0013	No Change

OPG provides responses to issues and questions raised by stakeholders and the public, and tracks issues and questions to identify trends in order to further refine proactive communications. Two-way dialogue with community stakeholders and residents is facilitated through personal contact, community newsletters, speaking engagements, advertising and educational outreach.

Through this regular outreach of an on-going nature, OPG continues to provide members of the public and interested parties with information regarding activities at the Pickering Waste Management Facility.

Community Committees

The Pickering Community Advisory Council (CAC) meets to exchange information and provide advice to senior station management on station activities as they relate to the adjacent community and public use of the waterfront trail and adjacent lands. Feedback for the waste management facility is obtained through this venue.

OPG also has a representative on the Durham Nuclear Health Committee (DNHC). OPG Nuclear staff make regular presentations to the DNHC on a variety of environmental, community outreach and operational issues. The committee is chaired by the Durham Region Medical Officer of Health.

Community Publications

OPG provides a community newsletter called “Neighbours” on a quarterly basis that are circulated by mail to residents throughout Durham Region (specific to the proximity of the respective nuclear power reactor stations). This provides an update of activities and events that occur at the respective stations.

These forums provide an opportunity for public engagement and information exchange regarding the storage of minimum 6-year cooled fuel at PWMF. Once the Licence Amendment application has been submitted, OPG will communicate the need to store minimum 6-year cooled fuel and status updates to the public through these communication tools.

Indigenous Nations Engagement

OPG acknowledges the Aboriginal and Treaty Rights of Indigenous Nations as recognized in the *Constitution Act, 1982*. Under its Indigenous Relations Policy, OPG regularly undertakes engagement with Indigenous Nations with established or asserted rights and/or interests.

Licence Renewal and the Duty to Consult

This amendment of the PWMF does not create any new adverse impacts on Aboriginal and/or treaty rights held by local Indigenous communities. However, while the duty to consult is not triggered by this activity, OPG will engage local Indigenous communities regardless as part of its preferred practice and in light of their interest in OPG nuclear operations.

Based on work undertaken through Indigenous engagement, OPG believes the following specific Indigenous Nations and communities continue to have a primary Aboriginal and/or treaty rights and interests with respect to OPG’s waste operations at the PWMF:

- Williams Treaties First Nations
- Mohawks of the Bay of Quinte
- Métis Nation of Ontario Region 8

OPG has engaged with these Indigenous Nations throughout 2022 and 2023 in order to provide them with information regarding activities at the PWMF (such as the in-service of SB4 in 2021) and to discuss any identified issues and concerns.

Once this Addendum to the Licence Amendment application to store minimum 6-year cooled fuel is submitted to the CNSC, OPG will engage with the Indigenous Nations identified above during regular scheduled meetings and briefing to share details on the need and scope of this proposal.

Conclusion

The need to store minimum 6-year cooled fuel at PWMF is an important initiative within OPG to support the Safe Storage Project at PNGS-B. OPG is requesting an amendment of the PWMF WFOL to add a new licensed activity to possess, transfer, package, manage and store minimum 6-year cooled fuel.

OPG is responsible for continued safe operation of the PWMF and confirms that the storage of minimum 6-year cooled fuel will be implemented based on a robust safety case. The proposed activities to support the storage of minimum 6-year cooled fuel will not compromise continued safe operation at PWMF, public and employee safety, and environmental protection.

The safety case for this project can be summarized as follows:

- Design: OPG has and will continue to follow its Engineering Change Control process, to ensure the design complies with applicable PWMF Licence Condition Handbook W4-350.00/2028 regulatory requirements and that configuration management for the facility is maintained.
- Continued Safe Operation: Safety analysis demonstrates that the storage of minimum 6-year cooled fuel will have a negligible effect on safe operation of PWMF, and on public and worker safety.
- Environmental Protection: An assessment of existing environmental-related submissions to the CNSC (environmental assessments, environmental risk assessment and predictive environmental effects assessment) concludes that the storage of minimum 6-year cooled fuel at PWMF will have negligible impact on the environment.
- Licensing Basis: The storage of minimum 6-year cooled fuel at PWMF will have negligible impact on PWMF's licensing basis, governance, programs and processes.

References: [2-1]. OPG Letter, K. Aggarwal to D. Saumure, "OPG – Change Request Application for Amendment to the Pickering Waste Management Facility (PWMF) Waste Facility Operating Licence WFOL W4-350.00/2028 ", June 20, 2023, e-Doc# 7068976, CD# 92896-CORR-00531-01478.
.

[2-2]. OPG Letter, K. Aggarwal to G. Steedman, "Proposal to Store Minimum 6-Year Old Used Fuel at the Pickering Waste Management Facility, November 5, 2020, e-Doc# 6416392, CD# 92896-CORR-00531-01397.

ENCLOSURE 1

OPG letter, K. Aggarwal to M. Bacon-Dussault, “OPG – Addendum to the Application for Amendment to the Pickering Waste Management Facility, Waste Facility Operating Licence WFOL-W4-350.00/2028”

CD# 92896-CORR-00531-01530 P

Storage of Dry Storage Containers (DSCs) containing less than 10 year old used fuel bundles at the Pickering Waste Management Facility (PWMF)

W-CORR-00531-01662

(26 total pages)

ONTARIO POWER GENERATION

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OPG Proprietary

Date: July 27, 2020

File No.: W-CORR-00531-01662

Lise Morton
VP Nuclear Waste Management
177 Tie Road, B21
Tiverton, On
N0G 2T0

Dear Lise Morton

Subject: Storage of Dry Storage Containers (DSCs) containing less than 10 year old used fuel bundles at the Pickering Waste Management Facility (PWMF)

References:

1. Letter from D. Howard to K. Talbot, "Pickering Waste Management Facility Thermal Performance Verification Program", dated June 10, 1997. NA44-CORR-N0014035.

2. OPG. Thermal Analysis of an Ontario Power Generation Dry Storage Container Containing Six-Year-Old 28 Or 37 - Element Fuel. Mar 20, 2014. 00104-REP-02308-00007 R00.

3. OPG. Structural Integrity Assessment of a Dry Storage Container Containing Six-Year-Old 28 - Element Fuel. Mar 5, 2014. 00104-REP-79171-00060 R00.

4. OPG. Structural Integrity Assessment of Dry Storage Container (DSC) Containing Six-Year-Old 28-element Fuel Under Postulated On-site Accident Scenarios. Sept 3, 2014. 00104-REP-79171-00061 R00.

5. OPG. Dose Rate Assessment Considering Lower Aged Fuel in PWMF SB3. Jun 15, 2020. 92896-REP-03200-00009 R00.

6. OPG. Email from C. Barua (OPG) to G. Steedman (CNSC). OPG Response To CNSC Question On OPG Submission Cd# 92896-CORR-00531-01355 In Support Of PWMF Safety Report 92896-SR-01320-10002 R006. Jun 29, 2020. 92896-CORR-00531-01381.

Introduction:

The purpose of this memo is to document OPG Environment's recommendation that a stand-alone environmental submission to the CNSC is not needed in order for OPG to perform loading, transfer, and interim storage of used fuel, that has observed a cooling period for a minimum of 6 years, from the Irradiated Fuel Bays (IFBs) to the existing PWMF Used Fuel Storage Building 3 (SB3) (a PWMF Phase II building), until a permanent storage solution becomes available.

The rationale for this decision was based on a review of the following documents:

Environmental assessments (EAs):

- Pickering Waste Management Facility Phase II Final Environmental Assessment Study Report. December 2003. 92896-REP-07701-00002
- Refurbishment and Continued Operation of Pickering B Nuclear Generating Station Environmental Assessment. December 2007. NK30-REP-07701-00002

Environmental Risk Assessment (ERA) and Predictive Effects Assessment (PEA):

- ERA for Pickering Nuclear. Feb 2018. P-REP-07701-00001 R001
- PEA for Pickering Nuclear Safe Storage. April 2017. P-REP-07701-00002 R000

Operating Licences and Handbooks:

- Nuclear Power Reactor Operating Licence. Pickering Nuclear Generating Station. PROL 48.00/2028.
- Pickering Nuclear Generating Station Nuclear Power Reactor. Licence Conditions Handbook. LCH-PR-48.00/2028-R000.
- Waste Facility Operating Licence. Pickering Waste Management Facility. WFOL-W4-350.0/2028.
- Pickering Waste Management Facility. Licence Conditions Handbook. LCH-W4-350.00/2028.

Record of Proceedings and Record of Decision:

- Record of Proceedings, Including Reasons for Decision. May 28, 2004. Subject: Environmental Assessment Screening Report on the proposed expansion of the Pickering Waste Management Facility (Phase II). Available online: http://www.nuclearsafety.gc.ca/eng/the-commission/pdf/Decision-OPG-PWMF-e.pdf

- Record of Proceedings, Including Reasons for Decision. December 10, 2008. Subject: Screening Environmental Assessment of the Pickering Nuclear Generating Station B Refurbishment and Continued Operations Project, Pickering, Ontario. Available online: http://www.suretenucleaire.gc.ca/eng/the-commission/pdf/2008-12-10-Decision-PickeringB-e-Edocs3330500.pdf

- Record of Decision. April 13, 2017. Subject: Application to Renew the Waste Facility Operating Licence for the Pickering. Available online: http://nuclearsafety.gc.ca/eng/the-commission/pdf/2017-04-13-Decision-OPG-PickeringWasteManagementFacility-e.pdf

Relevant sections considered in the above documents are presented in Attachment A (section A1 – A6).

Background:

As a common practice, used fuel from operating units at the Pickering Nuclear Generating Station (PNGS) is cooled in the IFBs for a minimum of 10 years before being transferred into DSCs, and placed into interim storage buildings in the PWMF. This practice is described in the PWMF Phase II EA, Pickering B Refurbishment and Continued Operation EA, Pickering Nuclear ERA, Pickering Nuclear Safe Storage PEA, and the Record of Proceedings associated with the EA of the Pickering B Refurbishment and Continued Operations**.**

Loading and interim storage of a DSC containing four modules of 6-year-old used fuel was successfully completed in May 1998 at the PWMF. Authorization at the time was given by Atomic Energy Control Board (AECB) (Reference 1). Repeating this infrequent practice in the future will enable OPG to create additional space in the IFB-B to allow for storage of fuel from Unit 5 to 8 to support permanent shutdown of the PNGS and planning of Pickering Safe Storage.

Summarized below is the outcome of the review.

Project scope

There is no change in project scope as described in the EA's. The project scope includes used fuel transfer and interim storage in the PWMF. It does not specify the age of the fuel allowed for transfer and storage. Refer to attachment A section A1 for more details.

Licensed activities and conditions:

There is no change to licensed activities and conditions. The Pickering Operating Licence and the WWMF Operating Licence together covers the transport, packaging, management and interim storage of the nuclear fuel. Loading and storing younger used fuel will not deviate from any of the licence conditions. Refer to attachment A section A2 for more details.

Cooling period of used fuel:

Although various documents (i.e. EA's, ERA, PEA, Record of Proceedings) describe how used fuel is cooled in the IFBs for a minimum of 10 years before being loaded, transferred, and stored (see attachment A section A3), it is still possible to initiate and implement a change to this current practice via existing OPG processes (e.g., Engineering Change and Control (ECC)).

Since the change to reduce the cooling period is not considered a 'Designated Project' under the Canadian Impact Assessment Act (IAA), there is no requirement to conduct an EA (or now referred to as an IA) under the Impact Assessment Act. Past EA's were completed as part of the licence application process to support their respective licensing decisions. Once the licensing decisions are made, EAs are not revised.

The 2017 ERA was provided to CNSC to support the PWMF and Pickering operating licence renewal application and an ERA is required to be routinely updated every 5 years as per RegDoc 2.9.1 (Environmental Principles, Assessment and Protection Measures). The routine ERA updates for PN will consider any impacts from recent changes in operational activities including fuel loading, transfer and storage. A decision is expected to be made in 2021 on whether there is a need to update the PEA based on any known activities that may potentially invalidate the bounding scenarios or assumptions made in the PEA. The change identified in this memo will be assessed as part of that decision.

Fuel integrity:

Younger used fuel is expected to have a higher thermal temperature than older used fuel. It is mentioned in the EA (92896-REP-07701-00002) that the temperature of the fuel in dry storage is an important factor in the assurance of fuel integrity and safety and a temperature of up to 300ºC can be considered safe. A maximum and conservative fuel sheath temperature of about 272ºC is predicted based on a thermal analysis of a DSC containing 6-year-old fuel (Reference 2), which is less than the 300ºC limit mentioned in the EA. Thermal stresses produced from 6 year old fuel stored in a DSC is also predicted not to compromise the containment and radiation shielding functions of the DSC under processing and storage accident conditions based on structural integrity analysis completed (Reference 3 and Reference 4).

As long as the fuel sheath temperature remains under the upper limit of 300ºC, there should be no additional environmental risks associated with fuel integrity. Refer to Attachment A section A4 for more details on the fuel integrity related descriptions found in the EAs.

Dose rates:

DSCs containing younger used fuel may have higher dose rates compared to those without depending on the average age and arrangement of used fuel bundles inside in the DSCs. The predicted dose rates and annual doses from SB3 (from a bounding scenario that includes storage of 100 DSCs containing only 6 year old decayed used fuel in SB3) are still well within the regulatory limit (i.e., 1 mSv/y for a member of the public). Dose rates at the existing protected area fence for the SB3 bounding scenario are expected to remain well within the radiation dose rate targets of ≤ 0.5 μSv/h at the PWMF II perimeter fence and ≤ 100 μSv/y at the PNGS site boundary, as proposed in recent communication with the CNSC (Reference 6). Dose rates at the Phase II protected area fence will continued to be measured and monitored and mitigating actions taken if required.

The storage of younger fuel will not pose an unacceptable risk to workers or members of the public nor will it likely to result in adverse effects on the environment provided that the ECC process and the ALARA principle are followed and that all the relevant conditions under the Pickering Nuclear and PWMF Operating Licences (e.g., to implement and maintain the radiation protection program, environmental protection program, waste management program, and packaging and transport program) continue to be met.

For more details on the dose rate predictions, see shielding assessment for PWMF using lower fuel age in SB3 (Reference 5). For more details on the dose rate related assessments completed in the past EA's and the relevant regulatory limit and targets, see attachment A section A5. For more details on the licence conditions, see attachment A section A1

Conclusion:

A stand-alone environmental submission to CNSC is not required since loading, transporting, and storage of used fuel, 6 year or older, is considered to be within the scope of the relevant project EAs and falls within the conditions of the Pickering Nuclear and PWMF Waste Operating Licences.

Prior to the implementation of the plan to load, transfer, and store younger used fuel, the PWMF Safety Report will be updated and the OPG ECC process will be followed to demonstrate that OPG will be able to maintain an adequate level of safety. Changes to existing governance stemming from the plan to load, transfer and store used fuel with a shorter cooling period than 10 years will also be managed through the ECC process.

Sincerely,

Raphael McCalla
Director
Environment Nuclear

RM/sl

cc. Cammie Cheng
Jason Wight
Paul Crowley
Rafi Asadi
Kapil Aggarwal
Mark Priest
Steve Bagshaw
Mark Ferry
Ram Kalyanasundaram
Cameron Spence

Attachment A

Supporting Information

Section A1

Scope of the Project:

SOURCE: Pickering Waste Management Facility Phase II Final Environmental Assessment Study Report. December 2003. 92896-REP-07701-00002

1.3.1 Scope of the Project

The physical works involved in this project are the storage buildings to be built for the dry storage containers; all facilities, systems and activities required for the construction and operation of PWMF II; and the facilities, systems and activities required for the construction and operation of PWMF Phase II; and the facilities, systems, and activities involved in the transfer of loaded welded DSCs from PWMF I to the storage buildings in PWMF II.

Associated operations and activities that are within the scope of the project include:

- Preparation of systems and facilities involved in the transfer of loaded welded DSCs
  - Transfer of loaded welded DSCs from the Processing Workshop or Storage Buildings 1 and 2 in PWMF I to Storage Buildings 3 and 4 in PWMF II.

SOURCE: Refurbishment and Continued Operation of Pickering B Nuclear Generating Station Environmental Assessment. December 2007. NK30-REP-07701-00002

1.4.2 Scope of the Project

The physical works for the Project are the PNGS B Units 5, 6, 7 and 8 and ancillary systems necessary for their operation through to about 2060.

As outlined in the EA Guidelines (Section 7.0, p.5), the scope of project will consider the following activities related to the continued operation of the refurbished reactors until about 2060, including:

- continued interim storage of used fuel at the Pickering Used Fuel Dry Storage Facility (PUFDSF) within the PWMF;
- interim storage for the additional used nuclear fuel and the refurbishment waste at the PWMF;

Section A2

Licensed activities and conditions

SOURCE: Nuclear Power Reactor Operating Licence Pickering Nuclear Generating Station PROL 48.00/2028

IV) LICENSED ACTIVITIES:

This licence authorizes the licensee to:

(i) operate the Pickering Nuclear Generating Station (hereinafter "the nuclear facility") at a site located in the City of Pickering, in the Regional Municipality of Durham, in the Province of Ontario;

(ii) possess, transfer, use, package, manage and store the nuclear substances that are required for, associated with, or arise from the activities described in (i);

(vi) transport Category II nuclear material by road vehicle from the nuclear facility spent fuel bay to the onsite waste storage facility;

VI) CONDITIONS:

4. Safety Analysis
4.1 The licensee shall implement and maintain a safety analysis program.

7. Radiation Protection
7.1 The licensee shall implement and maintain a radiation protection program, which includes a set of action levels. When the licensee becomes aware that an action level has been reached, the licensee shall notify the Commission within seven days.

9. Environmental Protection
9.1 The licensee shall implement and maintain an environmental protection program which includes a set of action levels. When the licensee becomes aware that an action level has been reached, the licensee shall notify the Commission within seven days.

11. Waste Management
11.1 The licensee shall implement and maintain a waste management program.

14. Packaging and Transport
14.1 The licensee shall implement and maintain a packaging and transport program.

SOURCE: Licence Conditions Handbook (LCH-PR-48.00/2028-R000) - Pickering Nuclear Generating Station Nuclear Power Reactor Operating Licence

Licence Condition G.1: Nuclear Substances

Activity (ii) in the licence authorizes the licensee to possess, transfer, use, package, manage and store nuclear substances.

Activity (vi) in the licence authorizes the licensee to transport Category II nuclear material i.e. fuel by road from Pickering NGS spent fuel bay to the onsite waste storage facility, The Pickering waste storage facility is licensed separately from the Pickering NGS licence (WFOL-W4-350.02/2018 – e-Doc 4002929). This activity is addressed as part of LC 14.1, which describes the packaging and transport program.

Licence Condition 14.1: Packaging and Transport Program

The licensee shall implement and maintain a packaging and transport program.

Preamble:

Every person who transports radioactive material, or requires it to be transported, shall act in accordance with the requirements of the Transportation of Dangerous Goods Regulations (TDGR) and the Packaging and Transport of Nuclear Substances Regulations, 2015 (PTNSR 2015).

The PTNSR 2015 and the TDGR provide specific requirements for the design of transport packages, the packaging, marking and labeling of packages and the handling and transport of nuclear substances.

The packaging and transport SCA includes the following specific areas (SpAs):
- Package design and maintenance;
- Packaging and transport; and
- Registration for use.

Compliance Verification Criteria:

Licensee Documents that Require Notification of Change		
Document #	**Title**	**Prior Notification**
W-PROG-WM-0002	Radioactive Material Transportation	No
N-STD-RA-0036	Radioactive Materials Transportation Emergency Response Plan	No

Package Design and Maintenance:
PTNSR 2015 apply to the packaging and transport of nuclear substances, including the design, production, use, inspection, maintenance and repair of packages, and the preparation, consigning, handling, loading, carriage and unloading of packages. Where necessary, OPG package designs are certified by the CNSC

Packaging and Transport (Program):
The licensee shall implement and maintain a packaging and transport program that will ensure compliance with the requirements of the TDGR and the PTNSR 2015 for all shipments of nuclear substances to and from the Pickering NGS site. Shipments of nuclear substances within the nuclear facility where access to the property is controlled are exempted from the application of TDGR and PTNSR 2015.

Registration and Use:
OPG's packaging and transport program also covers the registration for use of certified packages as required by the regulations.

Guidance:

Org / Document #	Title	Version
CNSC / REGDOC 2.14.1	Information Incorporated by Reference in Canada's Packaging and Transport of Nuclear Substance Regulations, 2015	2016

SOURCE: Waste Facility Operating Licence Pickering Waste Management Facility – WFOL-W4-350.0/2028

IV) LICENSED ACTIVITIES:

This licence authorizes the licensee to:

(i) operate the Pickering Waste Management Facility ("the facility") located at the Pickering Nuclear Generating Station, City of Pickering, Regional Municipality of Durham, Province of Ontario;

(ii) possess, transfer, use, process, package, manage, and store nuclear substances that are required for, associated with or arise from the activities described in (i);

(iii) transport Category II nuclear materials that are associated with the activities described in (i) on the site of the Pickering Nuclear Generating Station;

VI) CONDITIONS:

4 Safety Analysis
4.1 Safety Analysis Program
The licensee shall implement and maintain a safety analysis program.

7 Radiation Protection
7.1 Radiation Protection
The licensee shall implement and maintain a radiation protection program, which includes a set of action levels. When the licensee becomes aware that an action level has been reached, the licensee shall notify the Commission within seven days.

9 Environmental Protection
9.1 Environmental Protection

The licensee shall implement and maintain an environmental protection program, which includes a set of action levels. When the licensee becomes aware that an action level has been reached, the licensee shall notify the Commission within seven days.

10 EMERGENCY MANAGEMENT AND FIRE PROTECTION
10.1 Emergency Preparedness Program
The licensee shall implement and maintain an emergency preparedness program.
10.2 Fire Protection Program
The licensee shall implement and maintain a fire protection program.

11 Waste Management
11.1 Waste Management Program
The licensee shall implement and maintain a waste management program.

14 Packaging and Transport
14.1 Packaging and Transport Program
The licensee shall implement and maintain a packaging and transport program.

SOURCE: Pickering Waste Management Facility Licence Conditions Handbook LCH-W4-350.00/2028

Licence Condition 4.1 Safety Analysis Program

Compliance Verification Criteria
Licensee Documents that Require Notification of Change

Doc#	Title	Prior Notice
92896-SR-01320-10002	Pickering Waste Management Facility – Safety Report	Y

Licensing Basis Publications

Org	Doc#	Title
CSA Group	N292.0-14	General principles for the management of radioactive waste and irradiated fuel
CSA Group	N-292.2-13	Interim dry storage of irradiated fuel

The safety analysis report is to confirm that the consequences of a range of events are acceptable. It includes an integrated assessment of the facility to demonstrate, among other things, adequate safety for external events such as fires, floods, and tornados, and adequate protective features to ensure the effects of an event do not impair safety related systems, structures, and components (SSC).

Every 5 years, OPG shall submit a revised safety analysis report for the facility. CNSC staff review the safety analysis report to verify that OPG employs appropriate assumptions, applies adequate scope, and demonstrates acceptable results. The safety analysis report must demonstrate that the radiological consequences of accident scenarios do not exceed public dose limits.

Licensees shall carry out safety analyses to confirm that facility design changes will not result in a reduction of safety compared to the licensing basis, as per LC G.1. The safety analysis report shall:

- demonstrate compliance with public dose limits, the dose-related criteria, structural-integrity related criteria, the limits on process and safety parameters, and safety or safety-related system requirements;

- justify appropriateness of the technical solutions employed in the supporting justification of safety requirements; and,

- complement other analyses and evaluations in defining a complete set of design and operating requirements.

Licence Condition 7.1 Radiation Protection

The Radiation Protection Regulations require that the licensee implement a radiation protection program and also ascertain and record doses for each person who perform any duties in connection with any activity that is authorized by the NSCA or is present at a place where that activity is carried on. This program must ensure that doses to persons (including workers) do not exceed prescribed dose limits and are kept As Low As Reasonably Achievable (the ALARA principle), social and economic factors being taken into account.

The regulatory dose limit to workers and the general public are explicitly provided in sections 13, 14 and 15 of the Radiation Protection Regulations.

Licence Condition 11.1 Waste Management Program

With respect to the storage and management of spent nuclear fuel, the waste management program should reflect the fundamental safety concerns related to criticality, exposure, heat control, containment, and retrievability. That is, the systems that are designed and operated should assure subcriticality, control of radiation exposure, assure heat removal, assure containment, and allow retrievability.

Licence Condition 14.1 Packaging and Transport Program

Compliance Verification Criteria
Licensee Documents that Require Notification of Change

Doc#	Title	Prior Notice
W-PROG-WM-0002	Radioactive Material Transportation	N
N-STD-RA-0036	Radioactive Materials Transportation Emergency Response Plan	N
N-PROG-RA-0013	Radiation Protection	Y

Section A3

Description on the cooling duration of used fuel in IFBs:

SOURCE: ERA for Pickering Nuclear. Feb 2018. P-REP-07701-00001 R001

2.2.2.1.1 Used Fuel

Used fuel bundles are initially 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

SOURCE: PEA for Pickering Nuclear Safe Storage. April 2017. P-REP-07701-00002 R000

1.0 Introduction

Following shutdown, the activities at PN Generating Station would involve the four distinct phases outlined below.

1) A 2-3 year ***Stabilization Phase*** per unit to transition each unit, and the station as a whole, from their current operating states to their respective safe storage states. Stabilization activities will include defuelling and dewatering reactor units.

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

1.1 Project Overview

Many of the specific details of the Stabilization activities are not finalized; however, assumptions have been made to provide a conservative (i.e., worst case) assessment of effects resulting from the transition and safe storage state.

Activities specific to the Stabilization Phase include:

- removal of all nuclear fuel from the reactor units and transfer to the IFBs and auxiliary irradiated fuel bay (AIFB);

Activities during the Storage with Surveillance Phase include:

- continued operation/surveillance of the IFBs, including transfer of used fuel from the IFBs to DSCs for storage on the PWMF site. It is anticipated that the irradiated fuel bays will be required for up to 10 years of cooling;

1.3 PEA Goals, Approach and Scope

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

3.0 Stabilization and Storage with Surveillance Activities

The main elements of the Stabilization and Storage with Surveillance Phases include the following.

- Removal of all nuclear fuel from the reactor units and transfer of the fuel to an IFB for approximately up to 10 years of cooling. Continued operation/surveillance of the IFBs and AIFB are required until all irradiated fuel and other components stored in the fuel bays are transferred into DSCs for safe interim storage at the PWMF.

3.13 Pickering Waste Management Facility

Used fuel bundles will continue to be stored in an IFB up to 10 years and then transferred to DSCs for interim storage in the PWMF.

SOURCE: Pickering Waste Management Facility Phase II Final Environmental Assessment Study Report. December 2003. 92896-REP-07701-00002

Section 2.2.2.1 Development Background

Since 1996, used fuel that has been cooled for at least ten years in PN's IFBs has been routinely transferred into DSCs for dry storage at PWMF I.

Appendix C – Community and Stakeholder Consultation

C-6 Newsletters

PWMFII EA NEWS - May 2002, Issue One

When used fuel bundles are removed from the reactors at Pickering Nuclear, they are still highly radioactive. They have to be managed safely and responsibly for a long time. The first step is to cool the fuel bundles under water for up to 10 years in specially engineered used fuel bays. As the Pickering fuel bays become full, it is necessary to transfer the used fuel from the fuel bays to robust concrete and steel containers for dry storage in a specially designed facility on the station site.

C-6 Newsletters

PWMFII EA NEWS - September 2003, Issue Three

The initial used fuel dry storage facility, PWMF I, has been in operation since 1996. The facility uses a dry storage process that is a proven, safe and regulated technology, widely used by other nuclear facilities in Canada, the USA and other countries. The process involves removing used fuel bundles from the water-filled used fuel storage bays (after a minimum of 10 years in those bays) at PN and placing them in specially designed robust steel and concrete containers called "Dry Storage Container" or DSCs. The DSCs are then processed, sealed and transferred to the Used Fuel Dry Storage buildings.

C-7 Project Information Package

When used fuel bundles are removed from the reactors at Pickering Nuclear, they are still highly radioactive. They have to be managed safely and responsibly for a long time. The first step is to cool the fuel bundles under water for up to 10 years in specially engineered used fuel bays. As the Pickering fuel bays become full, it is necessary to transfer the used fuel from the fuel bays into robust concrete and steel containers and store them in a specially designed storage facility on the station site. The containers – called "Dry Storage Containers" (DSCs) - are engineered to last at least 50 years and will provide safe, interim storage until a long-term management program is in place.

Used fuel is stored for at least 10 years under water in fuel bays at Pickering Nuclear. The water keeps the fuel bundles cool and provides an effective radiation shield. This is normal practice at all OPG nuclear stations and elsewhere.

C-11 Presentation to the PN Community Advisory Council (CAC)

<u>Presentation to Community Advisory Council - February 19, 2002</u>

> After 10 years, the used fuel may be moved to dry storage, on site but separate from station operations.

<u>Pickering Nuclear Generating Station Community Advisory Council</u>
Pickering Nuclear Information Centre - March 18, 2003
Meeting Highlights

> Council Comment and Questions
> John Peters and Don Gorber responded to Council comments and questions:

- How did the EA address the effect of radiation over time?

  John: The contribution of PWMF II to gamma radiation over time depends on the age of the used fuel when it is loaded into the container. The EA took the worst case for calculating PWMF II contribution per year, fuel that is only 10 years old and put into the facility all at once.

Appendix D - Open House Information Panels

Phase II of the Pickering Waste Management Facility will:

- Be used to store only Pickering used fuel and only after it has spent at least ten years in the existing fuel bays within the stations (wet storage)

Appendix G – Review comments on draft EA Study Report and OPG's Responses

Comments from IER & Scimus Inc. in association with North-South Environmental on behalf of the City of Pickering, July 2003 on the PWMF II Draft EA Study Report

IER comment:

> The total capacity of the storage buildings is 1654 Dry Storage Containers (DSC's), only 7% more than the total number of DSC's expected. This does not appear to provide sufficient contingency against unforeseen problems (Section 2.2.1, page 2-1).

OPG response:

> OPG maintains an overall nuclear waste system plan which includes all waste streams that it manages. Part of the plan addresses contingency plans for all phases of used fuel management. The dry storage step is only for used fuel that has been cooled for at least 10 years in wet storage, so there is a long lead time in determining requirements for additional storage capacity. If additional storage capacity was needed in the future another storage building could be proposed after 2016 when SB #4 was commissioned, but before 2025 when all the SBs at PN are filled to capacity. No change in the EA Study Report is required.

SOURCE: Refurbishment and Continued Operation of Pickering B Nuclear Generating Station Environmental Assessment. December 2007. NK30-REP-07701-00002

2.12 Basis for the Environmental assessment

Table 2.12-1, referred to as the "Basis for Environmental Assessment", provides a listing and description of each of the works and activities associated with the Project. This information provides the basis for the assessment of the effects on each of the environmental components.

Table 2.12-1 Basis for EA Study

Project Phase / Works and Activities - Interim Storage of Used Fuel at PWMF:

Irradiated fuel is stored in the irradiated fuel storage bay for a minimum period of 10 years before being transferred to Dry Storage Containers (DSCs) for interim storage at PWMF until a long-term storage facility is available.

SOURCE: Record of Proceedings, Including Reasons for Decision. December 10, 2008. Subject: Screening Environmental Assessment of the Pickering Nuclear Generating Station B Refurbishment and Continued Operations Project, Pickering, Ontario

107. To address concerns raised by several intervenors on waste management, the Commission requested that OPG elaborates on the design of the dry-storage container used for used fuel storage and on the fuel cycle after the removal of fuel from the reactor…… To answer the fuel cycle portion of the question, OPG added that the fuel removed from the reactor is stored in water pools at the stations for a minimum of 10 years to allow the fuel to cool to about 0.1 % of the radioactivity levels present at the time of its removal from the reactor. The fuel is then transferred to dry-storage containers for storage until a disposal facility is available.

Section A4

Description on integrity of used fuel:

SOURCE: Pickering Waste Management Facility Phase II Final Environmental Assessment Study Report. December 2003. 92896-REP-07701-00002

2.3.1.1 DSC Design and Operating Conditions

The DSC provides the necessary radiation shielding and containment of radioactive materials. It is designed to provide a storage life of at least 50 years and to meet all shielding and containment integrity requirements over this period.

To permit future retrieval, used fuel bundles in dry storage need to remain structurally intact and retain sufficient strength to sustain the stresses associated with future handling and transport. This requires limiting cladding deformation by creep or other degradation processes such as oxidation in the uranium dioxide fuel pellets. The integrity of used fuel cladding is also a key requirement for radiological safety. The pellet and the zircaloy sheath provide a primary barrier to prevent the release of radionuclides. The DSC provides secondary containment for any radionuclides released by the fuel, in the event that the fuel cladding integrity was compromised.

Both cladding creep and fuel matrix oxidation, the processes that could lead to splitting of the fuel cladding, resulting in release of radionuclides into the DSC cavity, are temperature dependent processes. Therefore, the temperature of the fuel in dry storage is an important factor in the assurance of fuel integrity and safety. The provisions used to maintain used fuel integrity during storage include welded closure of the DSC and the addition of an inert helium atmosphere in the DSC cavity. Oxidation is also limited due to helium.

Analysis and measurements carried out at PUFDSF indicate that the maximum fuel cladding temperature does not exceed 175ºC in dry storage. When used fuel is stored in a helium atmosphere, temperatures of up to 300ºC can be considered safe for the planned storage period for intact used fuel in DSCs. The upper temperature limit ensures that creep strain remains within acceptable limits. The inert gas precludes oxidation processes. These storage conditions are also considered safe for dry storage of used fuel with minor cladding defects. The above considerations support the conclusion that under normal operating conditions, DSCs provide safe and retrievable storage for OPG's used nuclear fuel.

2.3.1.2 Factors Influencing Long-Term Integrity of the DSC and Used Fuel

The DSC has been designed to provide a storage life that will meet all shielding and containment integrity requirements over a minimum 50 year service life. Investigations were performed during DSC design regarding the integrity and stability of the DSC for different load cases over the 50 year service life. The DSC design is based on analyses of a range of considerations concerning the following:

- decay heat removal
- shielding
- containment
- structural integrity

2.3.1.3 DSC and Fuel Integrity under Credible Malfunction and Accident Scenarios

As part of the design process for the DSC, load scenarios approximating a range of potential accidents and malfunctions were studied. The scenarios included DSCs in a range of dry storage scenarios, and in a range of transfer methods.

Section A5

Dose, radiation, environmental effects, and mitigation:

SOURCE: Pickering Waste Management Facility Phase II Final Environmental Assessment Study Report. December 2003. 92896-REP-07701-00002

2.3.2.2 Radiation and Radioactivity Considerations in PWMF II Design

Radiation Shielding

The radiation dose rate targets for PWMF II, derived for a member of the general public, are as follows:

- ≤ 0.5 μSv/h at the PWMF II perimeter fence, based on maximum 2000 hours per year occupancy for non-Nuclear Energy Workers (non-NEWs),
- ≤ 10 μSv/y contribution at the PNGS exclusion zone boundary; this dose rate target is 1% of the CNSC dose rate limit of 1 mSv/y for a member of the public.

5.2.4.2 Regional/Local Study Area - Workers at PNGS and the PWMF I

The average individual doses to Nuclear Energy Workers (NEWs) at PNGS from both internal (i.e., inhaled or ingested) and external exposure sources were reported at 1.1 mSv/y, and the maximum individual dose was reported at 10 mSv in 2001. T hese doses are consistent with OPG's Exposure Control Level (ECL) of 10 mSv/y per calendar year, and are well below the CNSC regulatory limit of 50 mSv in any calendar year and 100 mSv over five calendar years (Canada Gazette 2000).

The baseline annual individual doses to workers (NEWs) at the PWMF I were taken from monitoring data. During 2001, nine operators at the PWMF I received an average individual dose of 0.64 mSv with a maximum of 1.94 mSv. Six mechanical maintainers who worked in the PWMF I reported measurable doses, with an average of 0.14 mSv and a maximum of 0.45 mSv (OPG 2002d). These occupational doses are consistent with OPG's ECL, and are well below the regulatory limit of 50 mSv in any calendar year and 100 mSv over five calendar years.

5.2.5.2 Site Study Area

The baseline dose from the existing environment to non-human biota in the Siting Area is attributable to two sources: i) natural background radiation and radioactivity (described in Section 5.2.5.1), and ii) licensed nuclear activities on the site.

Dose rates to biota in the Siting Area from radioactivity releases from the PNGS are attributable to external gamma radiation from radioactive noble gases, and from uptake and internal exposure to tritium and carbon-14; these dose rates were estimated at 0.11 µGy/d. The gamma dose rate (direct and skyshine gamma radiation) in the Siting Area from PWMF I was estimated at 0.03 µGy/d. The total dose rate from these sources was estimated at 0.14 µGy/d in this assessment.

In conclusion, the baseline dose to terrestrial fauna in the Siting Area was calculated to be 4.1 µGy/d, with over 90% of that contributed by natural background radiation and radioactivity. The corresponding dose to terrestrial flora was estimated in the range 1.8 to 20 µGy/d, also predominantly from natural background

7.3.1 Radiation and Radioactivity: Atmospheric Environment

7.3.1.2 Operations Phase – Likely Environmental Effects

The design of the Storage Buildings will provide for sufficient concrete shielding in the walls up to 30 cm (12") such that the gamma radiation level at the perimeter of the PWMF II site is predicted to be 0.13 µSv/h (Nuclear Safety Solutions 2003). This level meets the OPG target of < 0.5 µSv/h, corresponding to a dose < 1,000 µSv/y for 2000 h/y occupancy, the CNSC public dose limit (applicable for non-NEWs).
A dose rate of up to 50 µSv/h was predicted at the roof (Nuclear Safety Solutions 2003). This value was adopted in this assessment as a conservative estimate (i.e., overestimate) of the corresponding dose rate at the PWMF II. The predicted gamma radiation levels from full Storage Buildings located at Site Area B provides a dose rate of < 10 µSv/y at the PN east property boundary. This includes both direct and skyshine contributions. This is expected to increase the levels by less than three percent above a baseline of 350 µGy/y and will be indistinguishable from the temporal and spatial variations in natural background radiation levels at this location.

Identified Mitigation Measures

The gamma radiation from the DSCs was determined to be indistinguishable from background radiation levels at the PN east property boundary. The calculated dose rate meets OPG's dose targets and is well within CNSC's regulatory limit. Therefore, no mitigation measures are required.

7.3.2 Radiation and Radioactivity: Terrestrial Environment

7.3.2.2 Operations Phase – Likely Environmental Effects

The terrestrial environment will be affected by gamma radiation from DSCs. The effect of gamma radiation on the terrestrial environment from the operation of two Storage Buildings containing the full complement of loaded DSCs (approximately 1000) serves as the upper bound for both Project Works and Activities, including transfer of DSCs between PWMF I and PWMF II. The potential effects on birds perching on the roof, on flora and fauna at the exterior walls, and on flora and fauna at the perimeter of the PWMF II site boundary are described below.

Birds may perch on the roof of the Storage Buildings for brief periods, and be exposed to absorbed dose rates of approximately 0.05 mGy/h from gamma radiation. Exposure periods of one or two hours per day would result in dose rates of up to 0.2 mGy/d. This dose rate is less than the no-effect-level of 1 mGy/d reported by UNSCEAR (1996). Based on observations since the beginning of operation of PWMF I in 1996, birds have not nested on the roof of the PWMF I Storage Buildings 1 and 2, and therefore, are not expected to nest on the roof of the PWMF II.

The effects of gamma radiation on flora and on fauna with a limited range (e.g., field mouse) that live in the vicinity of the perimeter of the PWMF II site was evaluated by comparing estimated doses to no-effect levels reported by UNSCEAR. Fauna with a large range spend some of their time at distance from the Storage Buildings in lower radiation fields, and are expected to receive lower daily doses than the biota confined to the areas adjacent to the perimeter of the PWMF II site. Based on the assessment of the gamma radiation levels from loaded DSCs in the PWMF II Storage Buildings at the perimeter of the PWMF II site, the estimated daily dose rate to flora and fauna at that location is approximately 0.004 mGy/d. This is a small fraction of the no-effects level of 1 mGy/d reported by UNSCEAR (1996). This dose rate is expected to be within the range of natural background levels. Thus, the additional dose will be indistinguishable from the temporal and spatial variations in natural background radiation levels at this location.

Identified Mitigation Measures

Since the doses to flora and fauna are expected to be less than no-effect levels reported by UNSCEAR, no mitigation levels are required.

7.3.3 Radiation Doses to Members of the Public

7.3.3.2 Operations Phase - Likely Environmental Effects

Members of the public living and working outside the PN property boundary could potentially be affected by gamma radiation from DSCs during both of the Project Works and Activities listed above. The effect of gamma radiation on members of the public from two Storage Buildings containing the full complement of loaded DSCs (i.e., approximately 1000) serves as an upper bound for effects of both Project Works and Activities under normal operations. To ensure that all members of the public living, working or undertaking recreational activities beyond the PN property boundary are protected, a conservative estimate of the radiation dose to a hypothetical individual located year round at the PN east property boundary was compared to regulatory limits.

At the closest point on the site boundary to the PWMF II on Site Area B, the estimated annual dose from PWMF II, to a hypothetical individual located year round at the PN east property boundary was < 10 µSv (Nuclear Safety Solutions 2003), which is less than 1% of the CNSC regulatory limit of 1000 µSv/y. This annual dose is also below the level of regulatory concern of 10 µSv/y as recommended by the ACRP/ACNS (1988), and meets OPG's target of < 10 µSv/y for a member of the public.

The baseline dose to the hypothetical individual, as described in Section 5.2.4, is approximately 1,300 µSv/y from natural background radiation, and approximately 4.8 µSv/y from existing licensed operations at PN (OPG 2003d); therefore, the additional dose from the PWMF II project (< 10 µSv/y) is expected to be a very small fraction of the dose from natural background radiation, and will be indistinguishable from the temporal and spatial variations in radiation levels at this location (Figure 7.3-1).

Identified Mitigation Measures

Since it was determined that the additional dose from PWMF II to members of the public living, working or undertaking recreational activities outside the PN property boundary is expected to be a very small fraction of the dose from background radiation, it will be indistinguishable from the temporal and spatial variations in radiation levels. Therefore, no mitigation measures are required.

7.3.4 Radiation Doses to Workers

7.3.4.2 Operations Phase - Likely Environmental Effects

Workers (NEWs) Directly Involved with PWMF II

Doses to workers during normal operation at PWMF II were conservatively estimated on the basis of measured doses to workers at the PWMF I where similar activities to those identified for the PWMF II are carried out.

The individual doses to operators at PWMF II are expected to average 0.64 mSv/y with a maximum of 1.9 mSv/y. Individual doses to mechanical maintainers at PWMF II are expected to average 0.14 mSv/y with a maximum of 0.45 mSv/y. These annual doses to workers at PWMF II from normal operation are expected to be a small fraction of the regulatory limits, and well below OPG's ECL of 10 mSv/y.

PNGS Workers (NEWs)

The additional dose to individual PNGS workers from normal operation of the PWMF II (i.e., < 0.64 mSv/y) will be in addition to the baseline average annual dose received by PNGS workers of 1.1 mSv/y with a maximum of 10 mSv/y. Therefore, the average individual dose to a PN worker is predicted to be approximately 1.7 mSv/y (i.e., the sum from both activities). This is considered to be an over-estimate as the additional dose to PNGS workers from the PWMF II is expected to be much less than the average dose to workers at PWMF II. The doses from normal operation at PWMF II to PNGS workers (NEWs) are a small fraction of the CNSC's regulatory limit and OPG's ECL. Internal and external doses received by PNGS workers are monitored and reported as part of their cumulative annual dose.

<u>PN Workers (non-NEWs)</u>
PN workers (non-NEWs) who work outside the protected areas of the PWMF II and the PN will be exposed to low levels of gamma radiation from the PWMF II activities listed above and are subject to CNSC's regulatory limits on an annual dose of 1 mSv. The gamma dose rate at the security fence of the PWMF II will be maintained at levels below the OPG target of < 0.5 µSv/h (1,000 µSv for a 2,000 hour work year) (Nuclear Safety Solutions 2003). Therefore, the effects of normal operation of PWMF II on PN workers (non-NEWs) are expected to be below the regulatory limit.

Identified Mitigation Measures
Because the estimated doses to workers (both NEWs and non-NEWs) during normal operations at PWMF II were determined to be below CNSC's regulatory limits and below OPG's ECLs, no mitigation measures are required.

8.4 Radiation Dose Related to Radiological Malfunctions and Accidents

The assessment of the effects of radiological malfunctions and accidents focused on the two events during DSC on-site transfer and during DSC storage that have the potential to release radioactivity into the environment. The assessment of the effects of the release of tritium and krypton-85 following the bounding accident is based on releases of 1.4 x 1012 Bq of tritium and 7.8 x 1012 Bq of krypton-85 and is evaluated in a conservative manner.

Likely Environmental Effects
<u>Non-Human Biota</u>
The estimated dose from tritium and krypton-85 released following a bounding accident was calculated to be 0.0094 Gy which is less than 1% of the no-effect level (1 Gy) reported by UNSCEAR (1996).

<u>Members of the Public and PN Non-NEWs</u>
A preliminary estimate of the dose to members of the public at the PN property boundary was conservatively calculated at 1 µSv, based on PWMF I Safety Report methodology assumptions. This is a small fraction (0.1%) of the regulatory limit on annual dose to members of the public (Canada Gazette 2000). The estimated dose is below the level of regulatory concern as recommended by the ACRP/ACNS (1988), and the OPG dose target for malfunctions and accidents (i.e., that radiation doses to the public at the PN site boundary, following a postulated abnormal event or credible accident shall not exceed the annual public dose limit of 1,000 µSv). Also, the baseline annual dose to members of the public from licensed activities at the PN site is approximately 7 µSv/y, and from natural background radiation is approximately 1,300 µSv/y.

<u>PWMF II Workers (NEWs)</u>
The dose to workers at the PWMF II from the bounding malfunction and accident was estimated to be < 6 mSv, based on PWMF I Safety Report methodology assumptions. As discussed previously, the assumptions stated for the accident scenario are very conservative and extremely unlikely to occur. Nevertheless, if the bounding accident was postulated to occur near the end of a dosimetry year, the estimated dose to a worker at PWMF II could be in addition to a typical annual dose of approximately 0.64 mSv/y from normal operation. The total postulated dose for the year would be approximately 7 mSv, less than OPG's ECL of 10 mSv/y and a small fraction of the regulatory limit of 50 mSv in a calendar year, to a maximum of 100 mSv over a five-year period.

<u>PN Workers (NEWs)</u>
The dose to a worker at PN in proximity to a malfunction or accident is expected to be equal to or less than the corresponding dose to a PWMF II worker, i.e., 6 mSv as discussed above.

The individual dose to workers at PN from the bounding accident and malfunction would be in addition to the baseline dose received (average of 1.1 mSv/y). All internal and external doses received by workers at PN are monitored and are reported as part of their cumulative annual dose. If the accident was postulated to occur at the end of a dosimetry year, the average individual dose to a worker at PN is expected to be less than 7 mSv in that year, a small fraction of the regulatory limit. In some years, the annual dose to a few PN workers may approach the ECL of 10 mSv. If one of these workers were assumed to be exposed to the bounding malfunction or accident near the end of a dosimetry year, the total dose in the year could approach 16 mSv. This maximum postulated dose to a worker is also below the regulatory limit of 50 mSv in a calendar year, to a maximum of 100 mSv over a five-year period.

Identified Mitigation Measures
Radiation doses to workers and the public from radiological malfunctions and accidents are expected to be below CNSC's regulatory limits and OPG's ECLs. Also, radiation doses to nonhuman biota are expected to be below no-effects levels reported by UNSCEAR. Therefore, no mitigation measures are required.

9.4.3.2 Other Projects and Activities

<u>PWMF I</u>
The dose rate at the PN east property boundary from PWMF I operations has been estimated at 6 x 10-5 µSv/h (OPG 2002d), or a dose of 0.05 µSv/y to a member of the public assuming full occupancy at this location. This is a very small fraction of the CNSC regulatory limit of 1,000 µSv/y and is well below the level of concern recommended by the ACRP/ACNS.

9.5.1 Members of the Public

9.5.1.2 Identified Mitigation Measures

The estimated cumulative doses to the most exposed members of the public are expected to be small fractions of the CNSC regulatory limits; therefore, no mitigation measures are warranted.

9.5.2 Workers on the PN Property

9.5.2.1 Dose Levels

<u>PWMF II Workers (NEWs)</u>
In conclusion, cumulative radiation doses to PWMF II workers will be carefully controlled and monitored to ensure that OPG's ECL (< 10 mSv/y), which is well below regulatory dose limits, will not be exceeded.

<u>PN Workers (NEWs and Non-NEWs)</u>
In conclusion, cumulative radiation doses to PN workers will be carefully controlled and monitored to ensure that OPG's ECLs (< 1000 µSv/y to non-NEWs, and < 10 mSv/y to NEWs), which are below regulatory dose limits, will not be exceeded

9.5.2.2 Identified Mitigation Measures

The estimated cumulative dose to NEWs at the PWMF II and NEWs and non-NEWs at the PN, are expected to be less than CNSC regulatory limits; therefore, no mitigation measures are warranted or required.

9.5.3 Cumulative Dose to Non-Human Biota

The estimated cumulative dose to non-human biota is a small fraction (i.e., 5%) of the no-effects level (1 mGy/d) reported by UNSCEAR (1996) and is less than the corresponding values recommended by CNSC staff in a paper presented at the 2002 Conference on Ecological Risk Assessment in Australia (Bird et al. 2002)

9.5.3.2 Identified Mitigation Measures

The estimated cumulative dose to non-human biota is expected to be less than the no-effects levels reported by UNCSEAR; therefore, no mitigation measures are warranted or required.

SOURCE: Refurbishment and Continued Operation of Pickering B Nuclear Generating Station Environmental Assessment. December 2007. NK30-REP-07701-00002

5.9.2.3 Evaluation of Effects for Continued Operation

The predicted gamma radiation levels from full Storage Buildings provides a dose rate of ≤ 10 μSv/y at the PN property boundary, based on full occupancy 100% of the year. This includes both direct and skyshine contributions. The effect of gamma radiation on the terrestrial environment at the PN property boundary from the Storage Buildings is expected to be ≤ 10μSv/y. This effect will be indistinguishable from the temporal and spatial variations in natural background radiation levels at this location.

A dose rate of 50 μSv/h was predicted on the roof of the DSC Storage Buildings from an array of loaded DSCs completely filling the buildings. Nesting of birds on the roofs of storage buildings at PWMF I and PWMF II is discouraged by the very nature of the roof design. However, birds may perch on the roof of the Storage Buildings for brief periods, and be exposed to (absorbed) dose rates of approximately 0.05 mGy/h from gamma radiation. Exposure periods of one or two hours per day would result in dose rates of up to 0.1 mGy/d. This dose rate is less than the no effects level of 1 mGy/d reported by UNSCEAR (1996).

The gamma radiation levels from loaded DSCs in PWMF II Storage Buildings are predicted to produce a dose rate less than 0.5 μSv/h at the perimeter fence of the PWMF II site. Therefore, the corresponding absorbed dose rates to flora and fauna were estimated at 0.0005 mGy/h. The estimated daily dose rate to flora and fauna at the perimeter of the PWMF II site is approximately 0.012 mGy/d, and is a small fraction of the no-effects level of 1 mGy/d reported by UNSCEAR (1996). Also, the predicted dose rate is expected to be within the range of natural background, which is 0.004 to 0.02 mGy/d.

5.9.2.4 Identified Mitigation Measures

Similar to the Refurbishment Phase, the storage of the refurbishment waste is expected to have locally elevated gamma radiation levels which are predicted to be less than 0.5 μSv/h. This dose rate was established by OPG to ensure that even for 2000 h/y occupancy, the dose to a human would not exceed 1 mSv. In addition, however, a dose rate of 0.5 μSv/h is far below any relevant dose-rate criteria for non-human biota. Moreover, these levels are within the range of levels previously experienced at the PN site. Therefore, with the access to these storage areas closely controlled, there is no additional mitigation needed.

5.9.5.3 Evaluation of Effects for Continued Operation

The annual doses to individual NEWs during normal operation are well below the regulatory limits, a maximum of 50 mSv in a one-year dosimetry period and an average of 20 mSv in a one year dosimetry period (i.e., a cumulative dose of 100 mSv in five one-year dosimetry periods). In addition, doses will be controlled to ALARA using internal dose control limits, such as the ADL and ECL.

Doses to NEWs due to continued operation of the waste management facility will be the same as encountered presently at the PWMF (i.e., an average individual dose of approximately 0.64 mSv per year per worker). After completing the placement of the refurbishment waste into storage, there will only be maintenance and caretaking activities inside the storage buildings, and thus, future doses to workers at PWMF are expected to be comparable to existing doses.

5.9.5.4 Identified Mitigation Measures

Radiation doses to NEWs in the Regional and Local Study Areas from the Continued Operation of PNGS B following refurbishment are expected to be indistinguishable from the baseline doses from the PNGS in the Regional and Local Study Areas. Furthermore, the Continued Operation of PNGS B following refurbishment is expected to result in radiation doses to NEWs in the Site Study Area that are well below the corresponding regulatory limits, and within OPG dose targets and ECLs.

As no distinguishable changes in dose levels from baseline conditions are expected during refurbishment or continued operation, additional mitigation measures are not required.

5.9.6.3 Evaluation of Effects for Continued Operation

As mentioned previously, the access and movement of visitors and non-NEW workers on the PN site is controlled by OPG, and the radiation doses to these individuals from licensed activities on the PNGS site are controlled by OPG to ensure that they do not exceed 1 mSv/y, the regulatory limit on annual dose to non-NEWs (Canada Gazette 2000). At the perimeter fence of the PWMF II site, the dose rate is predicted to be less than 0.5 µSv/h which corresponds to a dose rate of < 1,000 µSv/y for 2,000 h/y occupancy, the CNSC public dose limit for non-NEWs (Canada Gazette 2000). It is highly unlikely that a non-NEW would spend appreciable time in this area and thus, the doses to non-NEWs are expected to be well below the CNSC public dose limit. Therefore, the radiation doses to non-NEWs from the continued operation are expected to be indistinguishable from the radiation doses from normal operation of the reactors and well below the regulatory limit of 1 mSv/y for non-NEWs.

5.9.6.4 Identified Mitigation Measures

Radiation doses to members of the public in the Regional and Local Study Areas from the continued operation of PNGS B following the refurbishment are expected to be indistinguishable from the baseline doses from the PNGS in the Regional and Local Study Areas. Furthermore, the continued operation following refurbishment is expected to result in radiation doses to visitors and non-NEW workers on the PN site (i.e., in the Site Study Area) that are less than the corresponding regulatory limit for members of the public of 1 mSv/y (Canada Gazette 2000). As no distinguishable changes in dose levels from baseline conditions are expected during refurbishment or continued operation, additional mitigation measures are not required.

Section A6

Description from Record of Proceedings and Record of Decision:

SOURCE: Record of Proceedings, Including Reasons for Decision. May 28, 2004.
Subject: Environmental Assessment Screening Report on the proposed expansion of the Pickering Waste Management Facility (Phase II)

4. Conclusion

The Commission concludes that the environmental assessment Screening Report attached to CMD 04-H7 (as amended) is complete and meets all of the applicable requirements of the Canadian Environmental Assessment Act.

The Commission concludes that the project, taking into account the appropriate mitigation measures identified in the Screening Report, is not likely to cause significant adverse environmental effects.

SOURCE: Record of Proceedings, Including Reasons for Decision. December 10, 2008.
Subject: Screening Environmental Assessment of the Pickering Nuclear Generating Station B Refurbishment and Continued Operations Project, Pickering, Ontario

17. The Commission reviewed the EA Screening Report and concluded that it is complete and in accordance with the requirements of the CEAA.

57. Based on its review of the Screening Report and the above-noted information provided on the record, the Commission concludes that the proposed project, taking into account the mitigation measures, described in section 8 of the EA Screening Report, is not likely to cause significant adverse effects to the environment.

107. To address concerns raised by several intervenors on waste management, the Commission requested that OPG elaborates on the design of the dry-storage container used for used fuel storage and on the fuel cycle after the removal of fuel from the reactor. OPG responded that the dry-storage container was a very robust container consisting of a 13mm-thick steel inner liner and a 13mm-thick steel outer liner with approximately half a metre of high-density reinforced concrete between those two liners. OPG added that the containers, without fuel, weigh approximately 70 tonnes and that they were extremely robust and very similar to those used elsewhere in North America and around the world. OPG noted that they had proven to be adequate for storing spent nuclear fuel for extended periods of time as long as fifty years. To answer the fuel cycle portion of the question, OPG added that the fuel removed from the reactor is stored in water pools at the stations for a minimum of 10 years to allow the fuel to cool to about 0.1 % of the radioactivity levels present at the time of its removal from the reactor. The fuel is then transferred to dry-storage containers for storage until a disposal facility is available.

SOURCE: Record of Decision. April 13, 2017.
Subject: Application to Renew the Waste Facility Operating Licence for the Pickering Waste Management Facility

110. Based on the information considered for this hearing, the Commission is satisfied that the ALARA concept is adequately applied to all PWMF activities.

113. CNSC staff informed the Commission that, in keeping with the ALARA principle, OPG had planned improvements to its radiation protection program during the proposed renewed licence period and CNSC staff would be closely monitoring these initiatives.
115. Based on the information provided for this hearing, the Commission is satisfied that doses to workers at the PWMF are adequately controlled.

121. Based on the information provided on the record for this hearing, the Commission concludes that, given the mitigation measures and safety programs that are in place and will be in place to control radiation hazards, OPG provides, and will continue to provide, adequate protection to the health and safety of persons and the environment throughout the proposed renewed licence period.

122. The Commission is satisfied that OPG's radiation protection program at the PWMF meets the requirements of the Radiation Protection Regulations.

131. The Commission concludes that the health and safety of workers and the public was adequately protected during the operation of the facility for the current licence period and that the health and safety of persons would also be adequately protected during the continued operation of the facility in the proposed renewed licence period.

157. Based on the information submitted by CNSC staff in the EA Report, the Commission is satisfied that the EA adequately shows that OPG made and will continue to make adequate provision for the protection of the environment and persons at the PWMF site.

158. The Commission is satisfied that OPG's and the CNSC's environmental monitoring show that the public and the environment around the PWMF site remain protected.

166. Based on the information presented on the record for this hearing, the Commission is satisfied that the ERAs were carried out satisfactorily and showed that OPG was adequately protecting the environment in the vicinity of the Pickering NGS, and therefore, the PWMF site.

168. Based on the assessment of the application and the information provided on the record at the hearing, the Commission is satisfied that, given the mitigation measures and safety programs that are in place to control hazards, OPG will provide adequate protection to the health and safety of persons and the environment throughout the proposed licence period.

218. Based on the information presented on the record for this hearing, the Commission is satisfied that OPG is meeting, and will continue to meet, regulatory requirements regarding packaging and transport.

ENCLOSURE 2

OPG letter, K. Aggarwal to M. Bacon-Dussault, “OPG – Addendum to the Application for Amendment to the Pickering Waste Management Facility, Waste Facility Operating Licence WFOL-W4-350.00/2028”

CD# 92896-CORR-00531-01530 P

Modification Design Requirements for Loading, Transferring, Processing and Storing Minimum 6-year-old Fuel at NSSP

92896-MDR-79171-00001

(14 total pages)

Title:

MODIFICATION DESIGN REQUIREMENTS FOR LOADING, TRANSFERRING, PROCESSING, AND STORING MINIMUM 6-YEAR-OLD FUEL AT NSSP

92896

Modification Design Requirements for:

SCI: 79171

System: Dry Storage Container

Associated EC Number(s): 154806
Associated Project Number: N/A

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Revision Summary

Revision Number	Affected Section	Description of Revisions
R001	All	• Requirement {R-002} from R000 has been removed. • Requirement {R-004} has been added. • Requirement {R-028} has been reworded for clarify. • Reference [R-7] has been added. • Reference [R-8] has been added. • All requirement and reference numbers have been updated throughout the document to reflect above changes.
R000	N/A	Initial Issue.

1.0 INTRODUCTION

The Dry Storage Container (SCI: 79171) is a nuclear safety related container with a design life of 50 years. Currently, it is defined in supporting licence documents (including Safety Report and PWMF Operating Policies and Procedures) for Pickering Waste Management Facility (PWMF) Operating License, WFOL-W4-350.00/2028 [R-1], that only fuel that have been cooled for 10 years or longer since discharged from the reactor (hereinafter referred to as minimum 10-year-old fuel) are to be loaded into a DSC for its on-site transfer, processing, and storage in a dry storage building for interim storage.

MEC 154806 has been initiated in order to support the OPG Safe Storage Project for Pickering NGS Units 5-8. By the end of December 2025, additional space for discharged used fuel will need to be allocated in the PNGS Irradiated Fuel Bay-B (IFB-B) for two full unit core dumps. The purpose of this modification is to create the additional space in the IFB-B by loading fuel that have been cooled for a period of 6 years or more but less than 10 years (hereinafter referred to as minimum 6-year-old fuel), as required. In November of 2020, OPG has sent a letter [R-2] to CNSC requesting their concurrence to load a minimum of 24 DSCs and a maximum of 100 DSCs with minimum 6-year-old fuel. In the course of the project, further analysis was conducted for IFB-B space projections for end of life defueling and the projected minimum number of DSCs to be loaded with minimum 6-year-old fuel has changed to 34 DSCs [R-3].

Loading of minimum 6-year-old fuel will have the following effects that are different from the current practice of loading DSCs with minimum 10-year-old fuel:

1) Higher heat output
2) Higher radiation output
3) Different composition and activities of releasable radionuclides

Upon implementation, a maximum of 100 DSCs will be loaded by 2025 inside the IFB-B with minimum 6-year-old fuel, transferred to and temporarily stored at Pickering Processing Building for processing, transferred to and temporarily stored at Storage Building 1 (SB1) for International Atomic Energy Agency (IAEA) Safeguard Seal application, and then transferred to and placed in Storage Building 3 (SB3) for dry interim storage for at least until they reach 10 years of age and become eligible for off-site transportation.

This Modification Design Requirement (MDR) lists requirements for the modification, MEC 154806.

2.0 DOCUMENT CONVENTIONS

The requirements and references in this document are each assigned with unique serial numbers. Each serial numbers are prefixed with ‘R-’.

The serial numbers for the requirements are enclosed in curly brackets (i.e. {R-000}).

Rationale and notes may follow a requirement, indicated in italics. They are not binding but provide context and further explanation to assist in understanding and applying the requirement.

The serial numbers for the references are enclosed in square brackets (i.e. [R-0]). The list of references can be found in Section 5.0, References.

3.0 DESIGN REQUIREMENTS

No changes will be made to the existing DSC physical configuration as shown in drawings [R-4] and specification [R-5]. Hence, the requirements from the existing DSC Design Requirements (DR) [R-6] remain effective and are applicable to this modification. For each of the following sections, applicable DSC DR sections are specified. Additional requirements are listed.

3.1 Nuclear Safety Design Requirements

The nuclear safety design requirements are specified in DSC DR [R-6] Section 12.1, ‘Nuclear Safety’.

3.2 Functional Requirements

The functional requirements are specified in DSC DR [R-6] Section 2.0, ‘Functional Requirements’.

3.3 Performance Requirements

The performance requirements are specified in DSC DR [R-6] Section 3.0, ‘Performance Requirements’.

Note that the following requirement {R-001} replaces the requirement (b) from section 3.0 'Performance Requirements' in DSC DR [R-6]:

{R-001} The DSC shall be capable of storing fuel that have been cooled for six (6) years or more in the irradiated fuel bays.

Rationale: Per the existing DSC DR [R-6], the DSCs were originally designed to store fuel that have been cooled for 10 years or more in the irradiated fuel bays. This modification must ensure that the existing DSCs are also capable of storing minimum 6-year-old fuel.

{R-002} *Note: This requirement has been removed in REV001 for being a repetition of requirement (g) from Section 3.0 'Performance Requirements' in DSC DR.*

Although not specific to this modification, the following requirement is applicable:

{R-003} The DSC shall be able to maintain the fuel sheath temperature of minimum 6-year-old fuel below 300°C.

Rationale: Previous analysis shows that the fuel integrity can be maintained for 30 years at sheath temperature of 330°C in dry air atmosphere and indefinitely at sheath temperature of 420°C in helium atmosphere [R-8]. The 300°C is a requirement that bounds both atmospheric conditions.

Note: The requirement to maintain the fuel sheath temperature below 300°C is also applicable to the existing DSCs with minimum 10-year-old fuels. However, this requirement has been included for clarity. The effect of higher heat output from minimum 6-year-old fuel on passive cooling capacity of DSC shall be assessed.

3.4 Interfacing Systems

{R-004} The increased heat output and radiation from minimum 6-year-old fuel shall not compromise the structural integrity, operability, and/or performance of all interfacing systems.

The interfacing systems are specified in DSC DR [R-6] Section 4.0, 'Interfacing Systems'.

Additionally, the following interfacing systems (or structures) may be impacted by this modification:

A) Nuclear Fuel Location and Storage History (NuFLASH) (SCI: 35030)

B) Transfer Clamp (SCI: 76199)
   (i) Lid-to-Base Elastomer Seal

C) Welding Equipment:
   (i) Weld Head Camera

D) Transporters:
   (i) Transporter Camera

E) Weld Inspection Equipment:
   (i) Phased Array Ultrasonic Testing (PAUT) System (SCI: 76556)

F) Workshop Heating, Ventilation, and Air Conditioning (HVAC) Systems:
   (i) Heating and Ventilation System (SCIs: 73900, 67390)
   (ii) Air Conditioning System (SCIs: 73990, 67399)

G) IFB-B Fuel Bay
   (i) Fixed Area Gamma Monitors (FAGMs, SCI: 67873)

H) Processing Building

I) Storage Building

(i) SB1

(ii) SB3

J) IAEA Surveillance Cameras in IFB-B, Processing Building, and Storage Buildings.

3.4.1 Basic Requirements Imposed on Electrical

{R-005} The increased heat output from the DSCs loaded with minimum 6-year-old fuel shall not cause the temperature of nearby electrical conductors to exceed the conductor temperature rating or conductor termination temperature of the connected systems and/or equipment, whichever is less.

3.4.2 Basic Requirements Imposed on Instrumentation and Control (I&C)

See item C), D), and J) in requirement {R-004}

3.4.3 Basic Requirements Imposed on Process/Mechanical

{R-006} DSCs with minimum 6-year-old fuel shall have weld surface temperature below 50°C at the time of PAUT inspection [R-9].

Note: PAUT is used for inspection of DSC Lid-to-Base Weld.

{R-007} DSCs with minimum 6-year-old fuel shall have weld surface temperature in the range from 5°C to 52°C at the time of liquid penetrant testing [R-10].

Note: Liquid penetrant testing is used for inspection of Drain and Drain Pin Weld.

{R-008} Existing ventilation systems in PB, SB1, and SB3 shall be able to maintain the DSC fuel sheath temperature below 300°C.

3.4.4 Basic Requirements Imposed on Radioactive Waste

Not applicable.

3.4.5 Basic Requirements Imposed on Non-Radioactive Waste Management

Not applicable.

3.4.6 Basic Requirements Imposed on Service Water

Not applicable.

3.4.7 Basic Requirements Imposed on Compressed Air Systems

Not applicable.

3.4.8 Basic Requirements Imposed on Civil Structure

{R-009} The increased heat output and radiation from DSCs containing minimum 6-year-old fuel shall not impact the structural integrity of the building floors.

3.4.9 Other Requirements

{R-010} The higher gamma radiation from DSCs loaded with minimum 6-year-old fuel shall not cause the IFB-B FAGM measurements to exceed the alarm setpoint of 0.3 mSv/h [R-11].

{R-011} NuFLASH in IFB-B and NSSP shall be capable of tracking and recording the location and status of DSCs loaded with minimum 6-year-old fuel.

{R-012} The increased heat output and radiation from DSCs containing minimum 6-year-old fuel shall not impact the structural integrity of the In-bay and Transfer Clamps. The Transfer and In-bay clamps were designed to retain the DSC lid onto its body under normal or credible accident conditions thus preventing the loss of used fuel shielding.

{R-013} The increased heat output and radiation from DSCs containing minimum 6-year-old fuel shall not impact the structural integrity of Lid-to-Base elastomer seal used with Transfer Clamp.

Note: The Lid-to-Base elastomer seal is used with the Transfer Clamp and considered as a part of the Transfer Clamp design.

3.5 Design Limits and Strength Requirements

The design limits and strength requirements are specified in DSC DR [R-6] Section 5.0, ‘Design Limits and Strength Requirements’.

Additionally,

{R-014} Under normal operating conditions, the increased thermal gradient and higher radiation due to loading of minimum 6-year-old fuel shall not compromise the structural integrity of the DSC.

{R-015} Under credible accident scenarios, the DSCs shall maintain containment and shielding of the fuel, but its structural competency for continued use may be compromised [R-6]. The effect of increased thermal loading and higher radiation from minimum 6-year-old fuel on DSC material shall be evaluated against all credible accident scenarios [R-7].

3.6 Seismic Requirements

The seismic requirements are specified in DSC DR [R-6] Section 6.0, 'Seismic Requirements'.

3.7 Design Constraints

{R-016} No changes shall be made to the existing DSC physical configuration as shown in drawings [R-4] and specification [R-5].

{R-017} The DSCs loaded with minimum 6-year-old fuel shall not be processed with 5/8" modification as per EC#120931.

Note: The scope of this modification does not include changes from future ECs (i.e. V groove modification) and 5/8" weld modification as per EC#120931. The effect of loading minimum 6-year-old fuel has only been analyzed for the current configuration of the DSC with 1-1/4" Lid to Base closure weld.

{R-018} The DSCs loaded with minimum 6-year-old fuel shall not be transported off-site until they reach 10 years of age. They shall be treated as on-site storage only until the fuel reaches to 10 years cooling period after discharged from the reactor cores.

{R-019} No more than 100 DSCs shall be loaded with minimum 6-year-old fuel per the letter sent to CNSC [R-2]

{R-020} The DSCs containing minimum 6-year-old fuel shall only be stored in SB3 for the purpose of interim on-site storage.

{R-021} The DSCs containing minimum 6-year-old fuel shall be temporarily stored in Processing Building and SB1 only for the purpose of processing and IAEA seal application, respectively.

Note: Evaluation shall be completed during the detailed design phase to determine the maximum allowed number of DSCs loaded with minimum 6-year-old fuel inside Processing Building and SB1 and ensure all the requirements as specified in this MDR are met.

3.8 Environment Qualification/Aging Considerations

The aging considerations are specified in DSC DR [R-6] Section 8.0, 'Environmental Requirements'. However, the DSC does not need to be environmentally qualified.

Additionally,

{R-022} The increased heat output from the minimum 6-year-old fuel shall not accelerate deterioration of the DSC coating

3.9 Reliability Requirements

The reliability requirements are specified in DSC DR [R-6] Section 9.0, ‘Reliability Requirements’.

3.10 Maintainability/Operability/Human Factor Requirements

The maintainability requirements are specified in DSC DR [R-6] Section 10.0, ‘Maintainability Requirements’.

Additionally,

{R-023} For touch-up coating application, the DSC surface temperature at the time of coating application shall meet the substrate temperature requirement specified in the coating manufacturer’s specification for PPG Amerlock 400 (self priming).

Note: The PPG Amerlock 400 (self priming) is used as the touchup coating in NSSP. The coating is used to coat the unpainted areas of DSCs and to cover any abnormal DSC coating defects.

{R-024} The DSCs loaded with minimum 6-year-old fuel at SB3 shall have markings with clear indication of their ages.

3.11 Periodic Inspection Requirements

The periodic inspection requirements are specified in DSC DR [R-6] Section 11.0, ‘Periodic Inspection Requirements’.

Additionally,

{R-025} The inspection plan shall have a clear instruction on how to identify the DSCs loaded with minimum 6-year-old fuel.

3.12 Safety Requirements

3.12.1 Radiation Safety Requirements

The radiation safety requirement is specified in DSC DR [R-6] Section 5.6, ‘Radiation Safety (Shielding) Requirements’.

Although not specific to this modification, for all facility buildings

{R-026} The radiation safety requirements [R-12] under normal operation due to the storage of DSCs loaded with minimum 6-year-old fuel are:

1. ≤ 0.5 μSv/h outside the Used Fuel Dry Storage (UFDS) areas, on a quarterly average basis, based on the CNSC dose limit of 1 mSv/year for a member of the public, over a maximum of 2,000 hours per year occupancy for non-NEWs.

2. ≤ 100 μSv/year at the Pickering site boundary. This is an administrative dose target of ten percent of the CNSC dose limit of 1 mSv/year for a member of the public.

3. ≤ 50 mSv for NEWs in any single year, and 100 mSv over 5 years.

{R-027} The radiation safety requirements [R-12] under abnormal event or credible accident due to the storage of DSCs loaded with minimum 6-year-old fuel are:

1. ≤ 1 mSv for the public at or beyond the OPG property boundary.

2. ≤ 50 mSv for the NEWs.

Note: The requirements in this section are also applicable to the existing DSCs with minimum 10-year-old fuels. However, these requirements have been included for clarity. The effects of higher radiation from DSCs with minimum 6-year-old fuel on dose rates measured at the site boundary and the facility fences shall be assessed.

3.12.2 Conventional Health and Safety Requirements

{R-028} Per OPG Hazardous Physical Agents Guide [R-13], heat stress controls should be considered if any of the following criteria is met:

a) Humidex reaches or exceeds 35°C
b) Environment Canada issues a humidex advisory
c) Dry bulb temperature in work area is greater than 30°C

Note: The increased heat output from DSCs containing 6-year-old fuel may increase the risk of worker heat stress.

{R-029} Increased DSC surface temperature may pose conventional safety hazard to personnel carrying out processing and inspection activities. Safe work planning and controls shall be in place to prevent contact hazard injuries, if required (refer to OPG-PROC-0129 [R-14]).

Rationale: According to ASTM C1055 – Standard Guide for Heated System Surface Conditions that Produce Contact Burn Injuries [R-15], there is no short term (that is, less than 6 hours) hazards if the surface temperature is below 44°C. If the surface temperature is in the range from 44°C to 70°C, short term hazards may exist, and thus, the bare skin contact time shall be limited. If the surface temperature exceeds 70°C, irreversible skin damage will occur.

3.12.3 Environmental Requirements

The environmental requirements are specified in DSC DR [R-6] Section 8.0, 'Environmental Requirements'.

3.12.4 Hazardous Agents or Substances

Not applicable.

3.13 Constructability Requirements

The constructability requirements are specified in DSC DR [R-6] Section 13.0, ‘Constructability’.

3.14 Commissioning Facilitation Requirements

Note: A Detailed Commissioning Specification is required to be completed per Section 7.5 of the Design Scoping Checklist associated with this modification (N-FORM-10959).

{R-030} Current practice and equipment shall be used to measure the dose rates on contact and at 1m distance (at any accessible point from the sides and the lid top) to ensure the nuclear safety requirements (Section 3.1 of this MDR) are met.

{R-031} The humidex and dry bulb temperature (ambient air temperature) shall be measured to ensure that the conventional safety requirement, Section 3.12.2 {R-028} of this MDR, is met.

{R-032} The DSC outer surface temperature shall be measured prior to any personnel coming in contact to ensure the conventional safety requirement, Section 3.12.2 {R-029} of this MDR, is met.

{R-033} The weld surface temperature shall be measured prior to PAUT inspection and Liquid Dye Penetrant Testing to ensure the interfacing systems requirements (Section 3.4.3, requirements {R-006} and {R-007} of this MDR) are met.

{R-034} Confirm that all equipment used for the temperature and dose rate measurements are properly calibrated.

3.15 Standards and Codes

The standards and codes are specified in DSC DR [R-6] Section 14.0, ‘Regulatory, Standards, and Codes’.

3.16 Cyber Security

Not applicable.

3.17 Other Requirements

None.

3.18 Comparison with Similar Systems in Other Generating Stations

In May of 1998, loading, processing, and interim storage of a DSC containing four modules of 6-year-old fuel was successfully completed. Authorization at the time was given by Atomic Energy Control Board (AECB) [R-16].

Note: Only one DSC was loaded with 6-year-old fuel in 1998, so the effects of multiple DSCs with 6-year-old fuel have not been determined. Thus, this modification is considered a First-of-a-Kind (FOAK).

4.0 IMPACT ON EXISTING SYSTEM DESIGN REQUIREMENTS

Existing DSC Design Requirement, 00104-DR-79171-10000 [R-6] will be affected by this modification. Updates to the DR document shall be made, as required.

Additionally, Design Requirements of systems/structures interfacing with DSC may be affected by this modification. They may include but are not limited to:

- PAUT Design Requirement [R-17]
- Workshop Heating & Ventilation Design Requirement [R-18]
- Used Fuel Dry Storage Facility Design Requirement [R-19]
- SB3 Design Requirement [R-20]
- Transfer Clamp Design Requirement [R-21]

5.0 REFERENCES

[R-1] WFOL-W4-350.00 2028, PWMF Operating License

[R-2] 92896-CORR-00531-01397, Proposal to Store Minimum 6-Year Old Used Fuel at the Pickering Waste Management Facility

[R-3] P-CORR-00990-1008210, IFB-B Space Projections for End of Life Defueling

[R-4] 00104-DRAW-79171-10051, Long Module Dry Storage Container – MK II General Arrangement

[R-5] 00104-TS-79171-00001, Used Fuel Dry Storage Ontario Power Generation Dry Storage Container (DSC)

[R-6] 00104-DR-79171-10000, Ontario Power Generation Used Fuel Dry Storage Container Design Requirements

[R-7] 92896-REP-01320-00012, Safety Assessment Storing Lower Aged Fuel in PWMF SB3

[R-8] 92896-CORR-03000-70063, Long-term Used Fuel Integrity in the Proposed Pickering NGS Dry Storage Facility

[R-9] I-IP-76556-50000, Procedure for Phased Array Ultrasonic Inspection of Waste Management's Dry Storage Container Lid Seal Weld

[R-10] I-IP-04163-50015, Liquid Penetrant Examination – Welding Quality Control

[R-11] NK30-DM-67873-00001, Fixed Area Gamma Radiation Monitoring

[R-12] 92896-SR-01320-10002, Pickering Waste Management Facility – Safety Report

[R-13] OPG-GUID-08963-0002, Hazardous Physical Agents Guide

[R-14] OPG-PROC-0129, Safe Work Planning

[R-15] ASTM C1055, Standard Guide for Heated System Surface Conditions that Produce Contact Burn Injuries

[R-16] 00104-CORR-79171-0139942, Additional Information Concerning Thermal Gradients Pertaining to Dry Storage Containers (DSCs)

[R-17] 00104-DR-76556-00001, Ultrasonic Inspection System for Dry Storage Container Lid Closure Weld

[R-18] 92896-73900, Workshop Heating & Ventilation

[R-19] 92896-DR-29642-00001, System Design Requirements – Used Fuel Dry Storage Facility (Previously Filed as 907-92896-86000)

[R-20] 92896-DR-01340-00001, Pickering Waste Management Facility Used Fuel Dry Storage Buildings No. 3 and No.4

[R-21] 92896-DM-76199-00001, DSC Lid Clamps - Used Fuel Dry Storage Facility Pickering NGS

ONTARIO POWER GENERATION

Kapil Aggarwal, M.Eng., P.Eng.
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OPG Proprietary

CD# 92896-CORR-00531-01533 P

February 14, 2024

Ms. Taline Kalindjian
Project Officer,
Wastes and Decommissioning Division
Canadian Nuclear Safety Commission
P.O. Box 1046
280 Slater Street
Ottawa, Ontario, K1P 5S9

Dear Ms. Kalindjian:

OPG - Response to CNSC Staff's Commitment Request Regarding DSC Commissioning in Respect of the Licensing Basis Amendment Application for Pickering Waste Management Facility Operating Licence W4-350.00/2028

The purpose of this letter is to provide a response to CNSC staff's commitment request regarding Dry Storage Container (DSC) commissioning in respect of the licensing basis amendment application for Pickering Waste Management Facility, Waste Facility Operating Licence W4-350.00/2028 (Reference 1).

In Reference 2, OPG stated that DSC outer surface temperatures and weld surface temperatures shall be measured during commissioning. OPG commits to providing dose rates and temperature measurements for both the weld surface and seal tube collected during commissioning with a comparison to predictions to CNSC staff no more than 30 days following collection of data. The results of these measurements will allow the IAEA and CNSC staff to verify the most appropriate way to apply safeguard measures on DSCs loaded with minimum 6-year cooled fuel. The loading of the minimum 6-year cooled fuel DSCs is anticipated to commence in Q3/Q4 2024.

To avoid introducing delay to OPG's loading and transfer campaign, OPG proposes CNSC staff presence at the facility during collection of this information to satisfy CNSC's need to verify compliance.

A new Regulatory Management Action Request will be initiated to submit DSC temperature measurements to CNSC staff no more than 30 days following collection of data for minimum 6-year cooled fuel DSCs.

Should you have any questions, please contact Ms. Liliana Moraru, Senior Manager, Regulatory Affairs – Strategic Projects at (905) 260-4089 or by email at liliana.moraru@opg.com.

Sincerely,

Kapil Aggarwal, M. Eng., P. Eng.
Vice President
Nuclear Sustainability Services
Ontario Power Generation Inc.

cc: N. Petseva - CNSC (Ottawa)
M. McLaughlin - CNSC (Ottawa)

References:

1. CNSC Letter, T. Kalindjian to L. Moraru, "Commitment Request to OPG Regarding DSC Commissioning in Respect of the Licensing Basis Amendment Application for Pickering Waste Management Facility Waste Facility WFOL W4-350.00/2028", January 24, 2024, e-Doc# 7205426, CD# 92896-CORR-00531-01534.

2. OPG Letter, K. Aggarwal to M. Bacon-Dussault, "Addendum to the Application for Amendment to the Pickering Waste Management Facility, Waste Facility Operating Licence WFOL-W4-350.00/2028", December 22, 2023, e-Doc# 7203226, CD# 92896-CORR-00531-01530.

Canada's Nuclear Regulator

e-Doc 5975449 (Word)
e-Doc 6344756 (PDF)

LICENCE CONDITIONS HANDBOOK

LCH-W4-350.00/2028
Pickering Waste Management Facility
Waste Facility Operating Licence

WFOL-W4-350.00/2028

Revision 1

Canadian Nuclear Safety Commission
Commission canadienne de sûreté nucléaire

Canada

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Licence Conditions Handbook
LCH-W4-350.00/2028
Pickering Waste Management Facility
Waste Facility Operating Licence
WFOL-W4-350.00/2028

SIGNED at OTTAWA this 22 day of July, 2020

Karine Glenn, Director
Wastes and Decommissioning Division
CANADIAN NUCLEAR SAFETY COMMISSION

e-Doc 5975449 (Word)
e-Doc 6344756 (PDF)

Revision History:

Effective Date	Revision	Word e-Doc and Version	Description of the Changes	Change Approval Form e-Doc
2018-06-12	R00	5156809 v6	Original document	N/A
2020-07-22	R01	5975449	Major changes to entire document. See 6266721	5975463

TABLE OF CONTENTS

INTRODUCTION

The general purpose of the Licence Conditions Handbook (LCH) is to identify and clarify the relevant parts of the licensing basis for each Licence Condition (LC). This will help ensure that the licensee maintains facility operation in accordance with the licensing basis for the facility and the intent of the licence. The LCH should be read in conjunction with the licence.

The LCH typically has three parts under each LC: the Preamble, Compliance Verification Criteria (CVC), and Guidance. The Preamble explains, as needed, the regulatory context, background, and/or history related to the LC. CVC are criteria used by Canadian Nuclear Safety Commission (CNSC) staff to verify and oversee compliance with the LC. Guidance is non-mandatory information, including direction, on how to comply with the LC.

Current versions of licensee documents listed in this LCH are recorded in e-Doc 5158818, which is controlled by the Wastes and Decommissioning Division (WDD) of the CNSC and is available to the licensee upon request.

This LCH has the following appendices:

- APPENDIX A, which describes the change control process;
- APPENDIX B, which includes a list of definitions and acronyms used in this LCH;
- APPENDIX C, which includes a list of licensing basis publications referenced in this LCH;
- APPENDIX D, which includes a list of licensee documents that require notification of change; and,
- APPENDIX E, which includes a list of guidance publications referenced in this LCH.

GENERAL

Licence Condition G.1 Licensing Basis for Licensed Activities

The licensee shall conduct the activities described in Part IV of this licence in accordance with the licensing basis, defined as:

(i) the regulatory requirements set out in the applicable laws and regulations;

(ii) the conditions and safety and control measures described in the facility's or activity's licence and the documents directly referenced in that licence;

(iii) the safety and control measures described in the licence application and the documents needed to support that licence application;

unless otherwise approved in writing by the Canadian Nuclear Safety Commission (hereinafter "the Commission").

Preamble

The licensing basis is discussed in REGDOC 3.5.3, *Regulatory Fundamentals.*

The standardized LCs, organized by Safety and Control Area (SCA), apply to all the licensed activities. Specific LCs were added for nuclear facility-specific activities, if required.

Compliance Verification Criteria

Licensee Documents that Require Notification of Change

Doc #	Title	Prior Notice
92896-CORR-00531-01031	Application for Renewal of Pickering Waste Management Facility Operating Licence	N
92896-CORR-00531-01075	Additional Information to Support the Application for Renewal of Pickering Waste Management Facility Operating Licence	N

Part (i) of the licensing basis includes, but is not limited to, the following.

- *Nuclear Safety Control Act*
- *Canadian Environmental Assessment Act*
- *Canadian Environmental Protection Act*
- *Nuclear Liability and Compensation Act*
- *Transportation of Dangerous Goods Act*
- *Access to Information Act*
- Canada/International Atomic Energy Agency (IAEA) Safeguards Agreement

The safety and control measures mentioned in the LC under Parts (ii) and (iii) of the licensing basis include important aspects of analysis, design, operation, etc. They may be found in high-level programmatic licensee documents but might also be found in lower-level, supporting documentation. They also include safety and control measures in licensing basis publications (e.g., CNSC REGDOC or Canadian Standards Association (CSA) Group standards) that are cited in the licence, the application, or in the licensee's supporting documentation.

Licensing basis publications are listed in tables in this LCH under the most relevant LC. All "shall" or normative statements in licensing basis publications are considered CVC unless stated otherwise. If any "should" or informative statements in licensing basis publications are also considered CVC, this is also explained under the most relevant LC.

The licensee documents in question, as well as the relevant licensing basis publications, may cite other documents that also contain safety and control measures (i.e., there may be safety and control measures in "nested" references). There is no predetermined limit to the degree of nesting at which relevant safety and control measures may be found.

LC G.1 requires the licensee to conform to, and/or implement, all the safety and control measures. Note, however, that not all details in referenced documents are necessarily considered to be safety and control measures.

- Details that are not directly relevant to safety and control measures for facilities or activities authorized by the licence are excluded from the licensing basis.
- Details that are relevant to a different SCA (i.e., not the one associated with the main document), are only part of the licensing basis to the extent that they are consistent with the main requirements for both SCAs.

The licensing basis is established by the Commission at the time the licence is issued. Per LC G.1, operation during the licence period that is not in accordance with the licensing basis is only allowed based on the written approval of the Commission. Similarly, only the Commission can change the licensing basis during the licence period; and this would also be expected to be recorded in writing.

In the event of any perceived or real conflict or inconsistency between two elements of the licensing basis, the licensee shall consult CNSC staff to determine the approach to resolve the issue.

This LC is not intended to unduly inhibit the ongoing management and operation of the facility or the licensee's ability to adapt to changing circumstances and continuously improve, in accordance with its management system. Where the licensing basis refers to specific configurations, methods, solutions, designs, etc., the licensee is free to propose alternate approaches as long as they remain, overall, in accordance with the licensing basis and have a neutral or positive impact on health, safety, the environment, security, and safeguards. However, the licensee shall assess changes to confirm that operations remain in accordance with the licensing basis.

Changes to certain licensee documents require written notification to the CNSC, even if they are in accordance with the licensing basis. Further information on this topic is provided under LC G.2.

For unapproved operation that is not in accordance with the licensing basis, the licensee shall take action as soon as practicable to return to a state consistent with the licensing basis, taking into account the risk significance of the situation.

In the event that the Commission grants approval to operate in a manner that is not in accordance with the existing licensing basis, this would effectively revise the licensing basis for the facility. The appropriate changes would be reflected in the CVC of the relevant LC.

Guidance

When the licensee becomes aware that a proposed change or activity might not be in accordance with the licensing basis, it should first seek direction from CNSC staff regarding the potential acceptability of this change or activity. The licensee should take into account that certain types of proposed changes might require significant lead times before CNSC staff can make recommendations and/or the Commission can properly consider them. Guidance for notifications to CNSC related to licensee changes are discussed under LC G.2.

Licence Condition G.2 Notification of Changes

The licensee shall give written notification of changes to the facility or its operation, including deviation from design, operating conditions, policies, programs and methods referred to in the licensing basis.

Preamble

CNSC staff tracks, in e-Doc 5158818, the version history of licensee documents that require notification of change (with the exception of security-related documents).

Licensee documents tabulated in the CVC of the LCH are subdivided into groups having different requirements for notification of change – ones that require prior written notification of changes and those that require written notification only. For the former type, the licensee shall submit the document to the CNSC prior to implementing the change. Typically, the requirement is to submit the proposed changes 30 days prior to planned implementation; however, the licensee shall allow sufficient time for the CNSC to review the change proportionate to its complexity and the importance of the safety and control measures being affected. For the latter type, the licensee need only submit the document at the time of implementing the change.

Compliance Verification Criteria

Licensee Documents that Require Notification of Change

Doc #	Title	Prior Notice
OPG-PROG-0001	Information Management	N
OPG-PROC-0019	Records and Document Management	N

Written notification is a physical or electronic communication from a person authorized to act on behalf of the licensee to a CNSC delegated authority or a CNSC staff member acting on behalf of a CNSC delegated authority.

In general, the changes for which the licensee shall notify the CNSC are captured as changes to specific licensee documents. The LCH identifies them under the most relevant LC. However, the licensee documents identified in the LCH only represent the minimum subset of documents that require notification of change. For any change that is not captured as a change to a document identified in the LCH, if it negatively impacts designs, operating conditions, policies, programs, methods, or other elements that are integral to the licensing basis, the licensee shall provide written notification of the change. For example, if a licensee document in the CVC refers to another document, including a third-party document, without citing the revision number of that document, if that document changes and the licensee uses the revised version, the licensee shall determine if it is necessary to notify the CNSC of the change.

The documents needed to support the licence application may include documents produced by third parties (e.g., reports prepared by third party contractors). Changes to these documents require written notification to the CNSC only if the new version continues to form part of the licensing basis. That is, if the licensee implements a new version of a document prepared by a third party, it shall inform the CNSC of the change(s), per LC G.2. On the other hand, if a third party has updated a certain document, but the licensee has not adopted the new version as part of its safety and control measures, the licensee is not required to inform the CNSC that the third party has changed the document.

Licensee documents tabulated in the CVC of the LCH are subdivided into groups having different requirements for notification of change – ones that require prior written notification of changes and those that require written notification only. For the former type, the licensee shall submit the document to the CNSC prior to implementing the change. Typically, the requirement is to submit the proposed changes 30 days prior to planned implementation; however, the licensee shall allow sufficient time for the CNSC to review the change proportionate to its complexity and the importance of the safety and control measures being affected. For the latter type, the licensee need only submit the document at the time of implementing the change.

Changes to the licensing basis that are not clearly in a safe direction require further assessment of impact to determine if prior Commission approval is required in accordance with LC G.1. Additional considerations for changes to facility operation or operating limits, conditions or procedures are discussed under LC 3.1 and those for facility design or equipment are discussed under LC 5.1

If the licensee document, or some part of it, also requires CNSC acceptance of change, a footnote has been added to the table. Such a requirement may be established in the document itself, in another LC, or in a licensing basis publication.

Written notifications shall include a summary description of the change, the rationale for the change, expected duration (if not a permanent change), and a summary explanation of how the licensee has concluded that the change remains in accordance with the licensing basis (e.g., an evaluation of the impact on health, safety, security, the environment and Canada's international obligations). A copy of the revised written notification document shall accompany the notification. All written notifications shall be transmitted to CNSC per established communications protocols.

The above also applies to a notice of change that requires CNSC staff acceptance, due to some other requirement in the licensing basis.

Changes that are not clearly in the safe direction require further assessment of impact to determine if Commission approval is required in accordance with LC G.1.

The licensee shall notify the CNSC in writing when it plans to implement a new licensing basis publication, including the date by which implementation of the publication will be complete. The notice shall indicate the corresponding changes to licensee documents listed in the CVC of the LCH.

Guidance

A list of criteria that could help determine if a change would be in accordance with the licensing basis is provided in Appendix A of e-Doc 4055483, *Assessing licensee changes to documents or operations*. Such criteria would also be used if the change requires CNSC staff acceptance, due to some other requirement in the licensing basis.

For proposed changes that would not be in accordance with the licensing basis, the Guidance for LC G.1 applies.

Licence Condition G.3 Financial Guarantee

The licensee shall maintain a financial guarantee for decommissioning that is acceptable to the Commission.

Preamble

The licensee is responsible for all costs of implementing the proposed decommissioning plan (see LC 11.2) and providing an appropriate financial guarantee that is acceptable to the Commission.

Ontario Power Generation Inc. (OPG) maintains a consolidated financial guarantee to cover the future decommissioning of all of its Ontario based Class I and waste nuclear substance licence facilities, and the long-term management of used fuel and all other radioactive waste. The current financial guarantee for OPG was accepted by the Commission on November 27, 2017. The financial guarantee and the associated decommissioning plans are required to be revised by OPG every five years or when requested by the Commission. The acceptance of the proposed financial guarantee is a subject of a separate Commission proceeding not related to the licence renewal process. The OPG consolidated financial guarantee includes:

1. Access to the Ontario Nuclear Funds Agreement (ONFA) segregated funds pursuant to the CNSC Financial Security and ONFA Access Agreement between OPG, the Province of Ontario, and the CNSC effective January 1, 2018 to December 31, 2022; and,
2. A trust fund for the management of used fuel established pursuant to the *Nuclear Fuel Waste Act*.

Compliance Verification Criteria

Licensee Documents that Require Notification of Change

Org	Doc #	Title	Prior Notice
Joint	N/A	CNSC Financial Security and ONFA Access Agreement between OPG, the Province of Ontario and the CNSC effective January 1, 2018	Y[1]

Note: [1]Requires CNSC acceptance of change.

Licensing Basis Publications

Org	Doc #	Title	Version	Effective Date
CSA Group	N294-09	Decommissioning of facilities containing nuclear substances	2009	Implemented
CSA Group	N294-19	Decommissioning of facilities containing nuclear substances	2019	See Transition

The financial guarantee for decommissioning the nuclear facility shall be reviewed and revised by the licensee every five years, or when the Commission requires, or following a revision of the preliminary decommissioning plan (PDP) that significantly impacts the financial guarantee.

The next full update to the five-year reference plan for financial guarantee purposes is expected in 2022.

The licensee shall submit annually to the Commission a written report confirming that the financial guarantee for decommissioning costs remains valid, in effect, and sufficient to meet the decommissioning needs. The licensee shall submit this report by the end of February of each year, or at any time as the Commission may request.

Transition

The licensee shall implement the requirements of CSA Group standard N 294-19, *Decommissioning of Facilities Containing Nuclear Substances* for the next scheduled FG revision due to the CNSC in 2022.

Guidance

Guidance Publications

Org	Doc #	Title
CNSC	G-219	Decommissioning Planning for Licensed Activities
CNSC	G-206	Financial Guarantees for the Decommissioning of Licensed Activities

Licence Condition G.4 Public Information and Disclosure

The licensee shall implement and maintain a public information and disclosure program.

Preamble

A public information and disclosure program (PIDP) is a regulatory requirement for licence applicants and licensees under the *Class I Nuclear Facilities Regulations*, paragraph 3(j), which requires that a licence application contain a description of a program to inform persons living in the vicinity of the site of the general nature and characteristics of the anticipated effects on the environment, health and safety of persons.

The primary goal of the PIDP, as it relates to the licensed activities, is to ensure that information related to the health, safety and security of persons and the environment, and other issues associated with the life cycle of nuclear facilities are effectively communicated to the public.

Compliance Verification Criteria

Licensee Documents that Require Notification of Change

Doc #	Title	Prior Notice
N-STD-AS-0013	Nuclear Public Information Disclosure	N

Licensing Basis Publications

Org	Doc #	Title	Version	Effective Date
CNSC	RD/GD-99.3	Public Information and Disclosure	2012	Implemented
CNSC	REGDOC 3.2.1	Public Information and Disclosure	2018	TBD

The PIDP shall include a commitment to and disclosure protocol for ongoing timely communication of information related to the licensed facility during the course of the licence period.

Transition

The licensee shall provide a gap analysis and implementation plan for the requirements of REGDOC-3.2.1, *Public Information and Disclosure*, by August 7, 2020.

Guidance

None provided.

SCA – MANAGEMENT SYSTEM

Licence Condition 1.1 Management System

The licensee shall implement and maintain a management system.

Preamble

The management system must satisfy the requirements set out in the regulations made pursuant to the NSCA, the licence and the measures necessary to ensure that safety is of paramount consideration in implementation of the management system. An adequately established and implemented management system for a waste facility provides CNSC staff confidence and evidence that the licensing basis remains valid.

Compliance Verification Criteria

Licensee Documents that Require Notification of Change

Doc #	Title	Prior Notice
OPG-PROG-0009	Items and Services Management	N
OPG-PROG-0010	Health and Safety Management System Program	N
N-STD-AS-0020	Nuclear Management Systems Organizations	N
N-PROC-AS-0077	Nuclear Safety Culture Assessment	N
N-STD-AS-0023	Nuclear Safety Oversight	N
N-POL-0001	Nuclear Safety Policy	N
N-CHAR-AS-0002	Nuclear Management System	Y

Licensing Basis Publications

Org	Document #	Title	Version	Effective Date
CSA	N286	Management system requirements for nuclear facilities	2012	Implemented

Guidance

Additional information can be found in CNSC regulatory document REGDOC-2.1.1, *Management System*

Licence Condition 1.2 Management of Contractors

The licensee shall ensure that every contractor working at the facility complies with this licence.

Preamble

This LC requires that the licensee retain responsibility for the protection of the health, safety, and security of the public and workers, and the protection of environment when contractors perform licensed activities.

Compliance Verification Criteria

The management of contractors will be evaluated against the following elements and principles:

- the risks to contractors and risks to the organization from the use of contractors are evaluated to identify, assess, and eliminate or control hazards;
- contractors are adequately trained in up-to-date procedures and are qualified and competent (i.e., education, certification, designation, training, knowledge, skills, experience, abilities, and attitudes) to conduct work within the licensed facility; and,
- work carried out by the contractor is approved by competent members of the licensee's staff and monitored by qualified personnel.

As defined by the *General Nuclear Safety and Control Regulations*, workers include contractors and temporary employees who perform work that is referred in the licence. Although contractors may perform certain licensed activities in these circumstances, OPG retains the responsibility that the facility remains compliant with the licence. As such, OPG is accountable to the CNSC to provide the required assurances that the health, safety, and security of the public and workers, and the environment are protected. This accountability to the CNSC cannot be delegated through contractual arrangements.

Guidance

None provided.

SCA – HUMAN PERFORMANCE MANAGEMENT

Licence Condition 2.1 Human Performance Program

The licensee shall implement and maintain a human performance program.

Preamble

Paragraph 3(d)(1) of the *Class I Nuclear Facilities Regulations* requires that a licence application contain the proposed human performance program for the activity to be licensed, including measures to ensure workers' fitness for duty.

It is important that the licensee continuously monitors human performance, takes steps to identify human performance weaknesses and mechanisms that will improve human performance and reduce the likelihood of nuclear safety events that are attributable to human performance.

Human factors are factors that influence human performance as it relates to the safety of a nuclear facility or activity over all design and operations phases. These factors may include the characteristics of a person, task, equipment, organization, environment, and training. The consideration of human factors in issues such as interface design, training, procedures, and organization and job design may affect the reliability of humans performing tasks under various conditions.

Compliance Verification Criteria

Licensee Documents that Require Notification of Change

Doc #	Title	Prior Notice
N-PROG-AS-0002	Human Performance	N
N-PROC-OP-0047	Hours Of Work Limits And Managing Worker Fatigue	Y

Licensing Basis Publications

Org	Document #	Title	Version	Effective Date
CNSC	REGDOC-2.2.4	Fitness for Duty: Managing Worker Fatigue	2017	Implemented
CNSC	REGDOC-2.2.4	Fitness for Duty, Volume II: Managing Alcohol and Drug Use, version 2	2017	See Transition
CNSC	REGDOC-2.1.2	Safety Culture	2018	November 26, 2020*

*OPG has implemented REGDOC-2.1.2, with the exception of nuclear security culture. OPG has committed to revise its governance to include nuclear security culture by November 26, 2020

Sections 4.5.2, 4.12, and 9.9.2 of CSA Group standard N286-12, *Management System Requirements for Nuclear Facilities* contain requirements for the management system to support excellence in worker performance.

Transition

With the exception of random alcohol and drug testing requirements, implementation of REGDOC-2.2.4, *Fitness for Duty, Volume II: Managing Alcohol and Drug Use* will be six months from the date of Commission approval and subsequent publication of REGDOC-2.2.4 Volume II, version 3. Implementation of random alcohol and drug testing component will be 12 months from the date of Commission approval and subsequent publication of REGDOC-2.2.4 Volume II, version 3. [Reference e-Doc 5865465]

Guidance

Guidance Publications

Org	Doc #	Title
CNSC	G-276	Human Factors Engineering Program Plans
CNSC	G-278	Human Factors Verification and Validation Plans
CNSC	REGDOC-2.2.5	Minimum Staff Complement
CNSC	REGDOC-2.2.1	Human Factors

Licensees should implement a program that continuously monitors human performance, takes steps to identify human performance weaknesses, improves human performance, and reduces the likelihood of human performance related causes and root causes of nuclear safety events.

The human performance program should address and integrate the range of human factors that influence human performance, which include, but may not be limited to the following:

- the provision of qualified staff;
- the reduction of human error;
- organizational support for safe work activities; and,
- the continuous improvement of human performance.

Licence Condition 2.2 Training Program

The licensee shall implement and maintain a training program.

Preamble

Paragraphs 12(1)(a) and 12(1)(b) of the *General Nuclear Safety and Control Regulations* require that licensees ensure that workers are trained and qualified to carry on the licensed activity safely.

Compliance Verification Criteria

Licensee Documents that Require Notification of Change

Doc #	Title	Prior Notice
N-PROC-TR-0008	Systematic Approach to Training	N
N-PROG-TR-0005	Training	N

Licensing Basis Publications

Org	Doc #	Title	Version	Effective Date
CNSC	REGDOC-2.2.2	Personnel Training	2016	Implemented

The licensee shall implement and maintain training programs for workers in accordance with CNSC regulatory document REGDOC-2.2.2, *Personnel Training*

Guidance

None provided.

SCA – OPERATING PERFORMANCE

Licence Condition 3.1 Operating Performance

The licensee shall implement and maintain an operating program, which includes a set of operating limits.

Preamble

None provided.

Compliance Verification Criteria

Licensee Documents that Require Notification of Change

Doc #	Title	Prior Notice
92896-CORR-00531-01031	Application for Renewal of Pickering Waste Management Facility Operating Licence	N
92896-CORR-00531-01075	Additional Information to Support the Application for Renewal of Pickering Waste Management Facility Operating Licence	N
W-PROG-WM-0001	Nuclear Waste Management	Y
92896-OPP-01911.1-00001	Operating Policies and Principles, Pickering Waste Management Facility	Y
92896-SR-01320-10002	Pickering Waste Management Facility – Safety Report	Y

This LC requires that OPG implement and maintain operating policies, programs, and procedures. These include:

- define the operating rules consistent with the safety report and other licensing support documentation within which the facility will be operated, maintained, and modified, all of which should ensure nuclear safety;
- specify the authorities of facility staff to make decisions within the defined boundaries; and,
- identify and differentiate between actions where discretion may be applied and where jurisdictional authorization is required.

OPG shall ensure that procedures are current, periodically reviewed and updated, and complied with at all times.

Guidance

None provided.

Licence Condition 3.2 Reporting Requirements

The licensee shall implement and maintain a program for reporting to the Commission or a person authorized by the Commission.

Preamble

This LC requires the licensee to implement and maintain a process for reporting information to the CNSC. This includes monitoring results, changes to facilities or approved activities, performance assessments and the occurrence of unusual events. Sections 29 and 30 of the *General Nuclear Safety and Control Regulations* provides further insight into reportable events.

Compliance Verification Criteria

Licensee Documents that Require Notification of Change

Doc #	Title	Prior Notice
N-PROG-RA-0002	Conduct of Regulatory Affairs	N
N-PROG-RA-0003	Performance Improvement	N
N-PROC-RA-0020	Preliminary Event Notification	N
92896-OPP-01911.1-00001	Operating Policies and Principles, Pickering Waste Management Facility	Y

Licensing Basis Publications

Org	Doc #	Title	Version	Effective Date
CNSC	RD/GD-99.3	Public Information and Disclosure	2012	Implemented
CNSC	REGDOC-3.2.1	Public Information and Disclosure	2018	TBD
CNSC	REGDOC 3.1.2	Reporting Requirements, Volume 1: Non-Power Reactor Class I Nuclear Facilities and Uranium Mines and Mills	2018	Implemented

CNSC staff will verify that OPG submits a written report within 90 days of the end of each calendar year quarter on the operations of the Pickering Waste Management Facility (PWMF) and an annual written report to the CNSC within 90 days of the end of the calendar year that summarizes the information submitted in their quarterly reports.

The quarterly reports should include the information outlined in REGDOC 3.1.2, at a minimum:

- the principal licensed activities completed;
- the results of OPG's monitoring programs;

- a summary description of events reported to the Commission pursuant to sections 29 and 30 of the *General Nuclear Safety and Control Regulations*;
- a summary description of any changes in the methods, procedures, and equipment used to carry out the licensed activities, and any modifications made to the facility;
- information concerning implementation of their public disclosure protocol associated with CNSC regulatory/guidance document RD/GD-99.3, *Public Information and Disclosure*; and,
- a trending analysis of operational performance.

Transition

The licensee shall provide a gap analysis and implementation plan for the requirements of REGDOC-3.2.1, *Public Information and Disclosure*, by August 7, 2020.

Guidance

For the purposes of efficiency, the annual report submission may be submitted with, and as a separate section of, the fourth quarterly operations report.

SCA – SAFETY ANALYSIS

Licence Condition 4.1 Safety Analysis Program

The licensee shall implement and maintain a safety analysis program.

Preamble

None provided.

Compliance Verification Criteria

Licensee Documents that Require Notification of Change

Doc #	Title	Prior Notice
N-PROG-MP-0014	Reactor Safety Program	N
92896-SR-01320-10002	Pickering Waste Management Facility – Safety Report	Y

Licensing Basis Publications

Org	Doc #	Title	Version	Effective Date
CSA Group	N292.0	General principles for the management of radioactive waste and irradiated fuel	2014	Implemented
CSA Group	N292.2	Interim dry storage of irradiated fuel	2013	Implemented
CSA Group	N292.3	Management of low- and intermediate-level radioactive waste	2014	Implemented
CSA Group	N286.7	Quality assurance of analytical, scientific, and design computer programs	2016	TBD

The safety analysis report is to confirm that the consequences of a range of events are acceptable. It includes an integrated assessment of the facility to demonstrate, among other things, adequate safety for external events such as fires, floods, and tornados, and adequate protective features to ensure the effects of an event do not impair safety-related systems, structures, and components (SSC).

Every five years, OPG shall submit a revised safety analysis report for the facility. CNSC staff review the safety analysis report to verify that OPG employs appropriate assumptions, applies adequate scope, and demonstrates acceptable results. The safety analysis report must demonstrate that the radiological consequences of accident scenarios do not exceed public dose limits.

Licensees shall carry out safety analyses to confirm that facility design changes will not result in a reduction of safety compared to the licensing basis, as per LC G.1. The safety analysis report shall:

- demonstrate compliance with public dose limits, the dose-related criteria, structural-integrity-related criteria, the limits on process and safety parameters, and safety or safety-related system requirements;
- justify appropriateness of the technical solutions employed in the supporting justification of safety requirements; and,
- complement other analyses and evaluations in defining a complete set of design and operating requirements.

OPG is expected to provide periodic updates to the report as needed or when there are major facility changes. The current safety analysis report for the PWMF was submitted to CNSC staff in 2018. The revised safety analysis report is due to be submitted to CNSC staff in 2023.

Transition

The licensee shall provide a gap analysis and implementation plan for the requirements CSA N286.7-16, *Quality Assurance of Analytical, Scientific, and Design Computer Programs*, by March 31, 2021

Guidance

None provided.

SCA – PHYSICAL DESIGN

Licence Condition 5.1 Design Program

The licensee shall implement and maintain a design program.

Preamble

None provided.

Compliance Verification Criteria

Licensee Documents that Require Notification of Change

Doc #	Title	Prior Notice
N-STD-MP-0028	Conduct of Engineering	N
N-STD-MP-0027	Configuration Management	N
N-PROG-MP-0009	Design Management	N
N-PROG-MP-0001	Engineering Change Control	N

Licensing Basis Publications

Org	Doc #	Title	Version	Effective Date
CSA Group	N393	Fire protection for facilities that process, handle, or store nuclear substances	2013	Implemented
NRC	N/A	National Building Code of Canada (2015)	2015	TBD
NRC	N/A	National Fire Code of Canada (2015)	2015	TBD

The licensee shall ensure that facility design and changes to facility design are accurately reflected in the safety analysis. Furthermore, the licensee shall ensure that facility status changes are controlled such that the facility is maintained and modified within the limits prescribed by the design basis and the licensing basis. Where the standards in those bases require specific reports, these shall be submitted to the CNSC.

The design of the nuclear facility and any modification shall comply with applicable codes, standards, and regulations including adequate consideration for human factors. For all current designs, the licensee shall modify and otherwise carry out work related to the nuclear facility in compliance with the applicable versions of the National Research Council Canada (NRC) *National Building Code of Canada* and the NRC *National Fire Code of Canada*.

The licensee shall, prior to implementing any proposed modification to the facility with the potential to impact protection from fire: arrange for a third-party review of the proposed modification, for compliance with the requirements set out in the applicable versions of the NRC *National Building Code of Canada* and the NRC *National Fire Code of Canada* ; have the review carried out by one or more independent external reviewers having specific expertise with such reviews; and, submit the results of the review in writing to CNSC staff.

The licensee shall design, build, modify, and otherwise carry out work related to the nuclear facility in compliance with CSA Group standard N393-13, *Fire Protection for Facilities That Process, Handle, or Store Nuclear Substances*, the NRC *National Building Code of Canada* (2015), and the NRC *National Fire Code of Canada* (2015) for any new designs, excluding the construction of the PWMF storage building 4 which shall be in compliance with the NRC *National Building Code of Canada* (2010), and the NRC *National Fire Code of Canada* (2010).

Guidance

Guidance Publications

Org	Doc #	Title
CNSC	G-276	Human Factors Engineering Program Plans
CNSC	G-278	Human Factors Verification and Validation Plans
CSA Group	N290.12	Human factors in design for nuclear power plants
CSA Group	N291	Requirements for safety-related structures for nuclear power plants

With regard to modifications, the design basis for the facility should be documented and maintained to reflect design changes to ensure adequate configuration management. The design basis should be maintained to reflect new information, operating experience, safety analyses, and the resolution of safety issues or the correction of deficiencies. The impacts of the design changes should be fully assessed, addressed, and accurately reflected in the safety analyses prior to implementation.

The design program should minimize the potential for human error and promote safe and reliable system performance through the consideration of human factors in the design of facilities, systems, and equipment.

Licence Condition 5.2 Pressure Boundary

The licensee shall implement and maintain a pressure boundary program and have in place a formal agreement with an Authorized Inspection Agency.

Preamble

This LC ensures that an Authorized Inspection Agency (AIA) will be subcontracted directly by the licensee. An AIA is an organization recognized by the CNSC as authorized to register designs and procedures, perform inspections, and other functions and activities as defined by CSA Group standard N285.0, *General Requirements for Pressure-Retaining Systems and Components in CANDU Nuclear Power Plants* and its applicable referenced publications (e.g., CSA Group standard B51, *Boiler, Pressure Vessel, and Pressure Piping Code* and the National Board Inspection Code). The AIA is accredited by the American Society of Mechanical Engineers (ASME) as stipulated by NCA-5121 of the ASME Boiler & Pressure Vessel Code.

Compliance Verification Criteria

Licensee Documents that Require Notification of Change

Doc #	Title	Prior Notice
N-LIST-00531-10003	Index to OPG Pressure Boundary Program Elements	N
N-MAN-01913.11-10000	Pressure Boundary Program Manual	N
N-CORR-00531-20012	Authorized Inspection Agency Service Agreement[1]	Y
N-PROC-MP-0082	Design Registration	Y
N-PROG-MP-0004	Pressure Boundary	Y
N-PROC-MP-0040	System and Item Classification	Y

Note: [1]Termination of the agreement is considered a change that requires prior written notification to the CNSC.

Licensing Basis Publications

Org	Doc #	Title	Version	Effective Date
ASME	B31.1	Power Piping	2010	Implemented
CSA Group	B51	Boiler, pressure vessel, and pressure piping code	2009 and Update No. 1	Implemented
CSA Group	N285.0	General requirements for pressure-retaining systems and components in CANDU nuclear power plants	2008 and Updates No. 1 and 2; and Annex N of N285.0-12 and Update No. 1	Implemented

Org	Doc #	Title	Version	Effective Date
NFPA	NFPA-24	Standard for the Installation of Private Fire Service Mains and Their Appurtenances	2010	Implemented
NFPA	NFPA-20	Standard for the Installation of Stationary Pumps for Fire Protection	2010 and Amendment 1 and Amendment 2	Implemented

For the purpose of the following, “registered”, “accepted”, and “approved” means either by the Commission or by a person authorized by the Commission, or by an AIA.

For the PWMF, OPG shall:

- Comply with CSA Group standard N285.0-08, *General Requirements for Pressure-Retaining Systems and Components in CANDU Nuclear Power Plants.*
- Design, manufacture, fabricate, install, modify, repair, test, examine, inspect, or otherwise perform work related to vessels, boilers, systems, piping, fittings, parts, components, and supports in accordance with the technical requirements in CSA Group standard N285.0-08, *General Requirements for Pressure-Retaining Systems and Components in CANDU Nuclear Power Plants*. Where indicated by this standard, OPG shall have the following:
  - registered designs for piping systems, components, fittings, and supports;
  - accepted overpressure protection reports;
  - approved code classifications, including applicable construction standards;
  - registered welding and brazing procedures;
  - accepted mechanical joint procedures;
  - qualified welders, welding operators, brazers, and examination personnel;
  - accepted quality assurance and quality control programs;
  - accepted plans and procedures; and,
  - markings for vessels, boilers, piping systems, fittings, parts, components, and supports.
- Operate vessels, boilers, piping systems, fittings, components, and supports safely and keep them in a safe condition. OPG shall:
  - follow accepted work plans and procedures to test, maintain, or alter overpressure protection devices;
  - comply with operating limits specified in certificates, orders, designs, overpressure protection reports, and applicable codes and standards; and,
  - have any certified boiler or vessel that is in operation or use inspected and certified by an authorized inspector according to an accepted schedule.

- Keep records of regulatory approvals and other documents required under this section and the standards applicable to the work or equipment.
- Personnel conducting non-destructive examinations shall be certified in accordance with the edition of CAN/CGSB 48.9712/ISO 9712 currently adopted for use by the National Certification Body of Natural Resources Canada for the appropriate examination method. If the National Certification Body does not offer certification for a specific inspection method, the relevant alternate requirements of Clause 11.3 of CSA Group standard N285.0-08, *General Requirements for Pressure-Retaining Systems and Components in CANDU Nuclear Power Plants* shall apply to ensure that personnel are appropriately trained and qualified.
- Have a formal agreement with an AIA to perform activities as defined in CSA Group standard N285.0-08, *General Requirements for Pressure-Retaining Systems and Components in CANDU Nuclear Power Plants*. OPG shall provide the Commission with a copy of the agreement.
- Maintain a pressure boundary program document roadmap in compliance with Annex N of CSA Group standard N285.0-12 (2012 and Update No. 1), *General Requirements for Pressure-Retaining Systems and Components in CANDU Nuclear Power Plants*.

Classification, Registration, and Reconciliation Procedures

OPG procedures describing the classification, registration, and reconciliation processes and the associated controls to ensure compliance with CSA Group standard N285.0-08, *General Requirements for Pressure-Retaining Systems and Components in CANDU Nuclear Power Plants* shall form a part of the pressure boundary program.

OPG shall provide prior written notification to the Commission, or to a person authorized by the Commission, of any changes to the procedures describing the classification, registration, and reconciliation process.

Overpressure Protection Report

OPG shall provide written notification to the Commission, or a person authorized by the Commission, of new or revised overpressure protection reports after the final registration. The notification may be provided in the form of a letter.

Quality Assurance and Quality Control Programs

OPG's pressure boundary quality assurance program shall comply with Clause 10 of CSA Group standard N285.0-08, *General Requirements for Pressure-Retaining Systems and Components in CANDU Nuclear Power Plants* except for Subclause 10.2.6. Repair and replacement activities are to comply with Subclause 10.3 of CSA Group standard N285.0-08, *General Requirements for Pressure-Retaining Systems and Components in CANDU Nuclear Power Plants*.

Class 6 or exempt-from-classification components that are required to be registered shall be subject to the quality requirements of CSA Group standard B51-09 (2009 and Update No. 1), *Boiler, Pressure Vessel, and Pressure Piping Code*. OPG's pressure boundary quality control programs for these components shall be reviewed and approved by the AIA.

Classification and Registration of Fire Protection Systems

Fire protection systems, and associated fittings and components are to be classified as Code Class 6, designed to ASME B31.1 (2010), *Power Piping*, and registered.

The following fittings and components may be exempt from requiring Canadian Registration Numbers provided they meet the following exemption criteria:

- fittings and components that are cUL or ULC listed and are suitable for the expected environmental conditions and maximum pressures; or
- pressurized cylinders and tubes such as extinguishers, inert gas and foam tanks, which bear Transport Canada approvals, and are suitable for the expected environmental conditions and maximum pressures; or
- buried fire protection piping when in compliance with NFPA-24 (2010), *Standard for the Installation of Private Fire Service Mains and Their Appurtenances*.

Testing of buried fire protection piping systems designed to the ASME piping codes may be exempt from ASME pressure testing requirements if the pressure testing is performed to NFPA-24 (2010), *Standard for the Installation of Private Fire Service Mains and Their Appurtenances*.

Authorized Inspection Agency

OPG shall arrange for the AIA inspectors to have access to all areas of the OPG facilities and records, and to the facilities and records of OPG's pressure boundary contractors and material organizations as necessary for the purposes of performing inspections and other activities required by CSA Group standard N285.0-08, *General Requirements for Pressure-Retaining Systems and Components in CANDU Nuclear Power Plants*.

A copy of the signed Agreement shall be provided to the CNSC. During the licence period, the licensee shall notify CNSC in writing of any change to the terms and conditions of the Agreement, including termination of the Agreement.

OPG shall provide the inspectors of the AIA with: information, reasonable advance notice, and time necessary to plan and perform inspections and other activities required by the standards.

Where a variance or deviation from the standard exists, the licensee must first submit the proposed resolution to the AIA for evaluation, and then to the CNSC for consent. The licensee must demonstrate that meeting the code requirement is impracticable and the proposed resolution shall not be implemented without the prior written consent of CNSC staff. A variance or deviation related to Code Edition, Code Classification, and Legacy Registration issues may be submitted directly to the CNSC without prior AIA evaluation.

Design registration services for pressure boundaries shall be provided by an AIA legally entitled under the *Provincial Boilers and Pressure Vessels Acts* and Regulations to register designs. Registration of piping systems shall be done by the Technical Standards and Safety Authority who are legally entitled to register designs in Ontario.

Delegation of Authority

The statement "or a person authorized by the Commission" reflects to whom the Commission has delegated certain authority. The delegation of authority by the Commission to act as a "person authorized by the Commission" is applied to the incumbents of the following positions:

- Director, Wastes and Decommissioning Division;
- Director General, Directorate of Nuclear Cycle and Facilities Regulations; and,
- Executive Vice-President and Chief Regulatory Operations Officer, Regulatory Operations Branch.

Guidance

Guidance Publications

Org	Doc #	Title
OPG	N-REF-01913.11-10001	Temporary Leak Maintenance by Leak Mitigation Process

SCA – FITNESS FOR SERVICE

Licence Condition 6.1 Fitness for Service Program

The licensee shall implement and maintain a fitness for service program.

Preamble

The SCA Fitness for Service covers activities that impact the physical condition of SSCs to ensure that they remain effective over time. Fitness for service includes programs that ensure equipment is available to perform its intended design function when called upon to do so.

This is accomplished by establishing an integrated set of programs and activities that ensure that safety performance requirements for critical SSCs are met on an ongoing basis. Aging management includes practices which address physical aging of SSCs as well as obsolescence issues as technology changes.

Compliance Verification Criteria

Licensee Documents that Require Notification of Change

Doc #	Title	Prior Notice
N-STD-MP-0028	Conduct of Engineering	N
N-PROG-MP-0009	Design Management	N
N-PROG-MA-0026	Equipment Reliability	N
N-PROG-MP-0008	Integrated Aging Management	N
W-PROG-WM-0001	Nuclear Waste Management	Y
00104-PLAN-79171-00002	Ontario Power Generation Dry Storage Container – Base (Underside) Inspection Plan	Y
00104-PLAN-79171-00001	Used Fuel Dry Storage Container Aging Management Plan	Y

Licensing Basis Publications

Org	Doc #	Title	Version	Effective Date
CNSC	REGDOC-2.6.3	Aging Management	2014	Implemented

For nuclear-related SSCs identified in accordance with OPG document N-STD-MP-0028, *Conduct of Engineering*, OPG shall establish inspection, testing and maintenance programs required to ensure continued safe operation of the facility.

Every year, the licensee shall include and submit to CNSC staff the inspection results and their evaluations, resulting from the in-service inspections and aging management of Dry Storage Containers (DSCs) in accordance with OPG document 00104-PLAN-79171-00001, *Used Fuel Dry Storage Container Aging Management Plan* and OPG document 00104-PLAN-79171-00002, *Ontario Power Generation Dry Storage Container – Base (Underside) Inspection Plan*, as part of the annual report.

Guidance

Guidance Publications

Org	Doc #	Title
IAEA	SSG-15	Storage of Spent Nuclear Fuel
CSA Group	N291	Requirements for safety-related structures for nuclear power plants
CNSC	REGDOC-2.6.2	Maintenance Programs for Nuclear Power Plants

The licensee should develop and implement life cycle management plans for nuclear safety-related pressure boundary systems and components and an aging management plan for safety-related structures.

The life cycle management plans for nuclear safety-related pressure boundary systems and components, and the aging management plan for safety-related structures should apply a systematic and integrated approach to establish, implement, and improve programs to manage aging and obsolescence of SSCs. The life cycle management plans should include structured, forward looking inspection and maintenance schedules, requirements to monitor and trend aging effects and any preventative actions necessary to minimize and control aging degradation of the SSCs.

SCA – RADIATION PROTECTION

Licence Condition 7.1 Radiation Protection

> The licensee shall implement and maintain a radiation protection program, which includes a set of action levels. When the licensee becomes aware that an action level has been reached, the licensee shall notify the Commission within seven days.

Preamble

The *Radiation Protection Regulations* require that the licensee implement a radiation protection program and also ascertain and record doses for each person who perform any duties in connection with any activity that is authorized by the NSCA or is present at a place where that activity is carried on. This program must ensure that doses to persons (including workers) do not exceed prescribed dose limits and are kept As Low As Reasonably Achievable (the ALARA principle), social and economic factors being taken into account.

The regulatory dose limit to workers and the general public are explicitly provided in the *Radiation Protection Regulations*.

Action levels (ALs) are designed to alert licensees before regulatory dose limits are reached. By definition, if an AL referred to in a licence is reached, a loss of control of some part of the associated radiation protection program may have occurred, and specific action is required, as defined in the *Radiation Protection Regulations* and the licence. ALs are not intended to be static and are to reflect operating conditions in the facility.

Specific regulatory requirements related to the implementation of all aspects of a radiation protection program, including ALs are found in the *Radiation Protection Regulations*, *Class I Nuclear Facilities Regulations*, *General Nuclear Safety and Control Regulations*, and *Nuclear Substances and Radiation Devices Regulations*.

Compliance Verification Criteria

Licensee Documents that Require Notification of Change

Doc #	Title	Prior Notice
N-REP-03420-10011	Occupational Radiation Protection Action Levels for Nuclear Waste Management Facilities	Y
N-PROG-RA-0013	Radiation Protection	Y

A written report shall be submitted by the licensee to the Commission within 21 days of the licensee becoming aware that an AL has been reached.

The current ALs for the PWMF are given in the table below. In the event of a discrepancy between the table below and the licensee documentation upon which they are based, the licensee documentation shall be considered the authoritative source.

Application	Action Level	Observations
Dose to Workers Individual worker external whole body radiation dose received on a job greater than planned.	0.5 mSv (50 mrem)	The AL is exceeded if a person receives an external whole body dose that equals or exceeds 0.5 mSv above the Electronic Personal Dosimeter dose alarm set point in a shift.
Worker Exposure Individual worker receives a single intake of tritium oxide in which the unplanned component is estimated over a predetermined activity.	600 kBq/L (16 µCi/L)	The AL is exceeded if a person receives a single intake of tritium oxide (tritiated water) in which the unplanned component of the initial concentration immediately after intake is estimated to equal or exceed 600 kBq/L (16 µCi/L) (representing a nominal unplanned exposure of 0.5 mSv [50 mrem]).
Worker Exposure Individual worker receives an intake of a radionuclide other than tritium attributable to a single event that equals or exceeds a predetermined activity.	0.025 of an Annual Limit of Intake	The AL is exceeded if a person receives an intake of a radionuclide other than tritium (in the form of tritium oxide) attributable to a single event that equals or exceeds 0.025 of an Annual Limit of Intake as defined in International Commission on Radiation Protection (ICRP) 68 *Dose Coefficients for Intakes of Radionuclides by Workers* (representing a nominal unplanned exposure of 0.5 mSv [50 mrem]).
Contamination Control Total surface contamination levels greater than a predetermined activity in Zone 1.	3.7×10^4 Bq/m^2 (1 µCi/m^2) (beta-gamma) 3.7×10^3 Bq/m^2 (0.1 µCi/m^2) (alpha)	The AL is exceeded if the total (fixed and loose) surface contamination levels greater than 3.7×10^4 Bq/m^2 (1 µCi/m^2) (beta-gamma) or 3.7×10^3 Bq/m^2 (0.1 µCi/m^2) (alpha) are found in Zone 1.

The licensee shall review and, if necessary, revise the ALs specified above at least once every five years in order to validate their effectiveness. The results of such reviews shall be provided to CNSC staff for review and acceptance. CNSC staff expect the ALs to be next reviewed, and revised if necessary, in 2022.

Guidance

Guidance Publications

Org	Doc #	Title
CNSC	G-129	Keeping Radiation Exposures and Doses "As Low As Reasonably Achievable (ALARA)"
CNSC	G-228	Developing and Using Action Levels

SCA – CONVENTIONAL HEALTH AND SAFETY

Licence Condition 8.1 Conventional Health and Safety

The licensee shall implement and maintain a conventional health and safety program.

Preamble

As of April 1, 1998, nuclear facilities owned and operated by Ontario Hydro were exempted from application of Part I, Part II, and Part III of the *Canada Labour Code*. This was established as per the following Consolidated Regulations: *SOR/98-179*, *SOR/98-180*, and *SOR/98-181*. The PWMF is now regulated by the *Occupational Health and Safety Act of Ontario* and the *Labour Relations Act*. Should any inconsistencies arise between the provincial and federal legislations, the federal laws would prevail to the extent of the inconsistency.

Compliance Verification Criteria

Licensee Documents that Require Notification of Change

Doc #	Title	Prior Notice
OPG-POL-0001	Employee Health and Safety Policy	N
OPG-PROG-0010	Health and Safety Management System Program	N

The licensee has the prime responsibility for safety at all times. This responsibility cannot be delegated or contracted to another organization or entity. The licensee shall ensure that contractors and other organizations present on site are informed of, and uphold their roles and responsibilities related to conventional health and safety.

Guidance

None provided.

SCA – ENVIRONMENTAL PROTECTION

Licence Condition 9.1 Environmental Protection

The licensee shall implement and maintain an environmental protection program, which includes a set of action levels. When the licensee becomes aware that an action level has been reached, the licensee shall notify the Commission within seven days.

Preamble

Licensees set Environmental Action Levels (EAL) and related parameters, so as to provide early warnings of any actual or potential losses of control of the environmental protection program. EALs are precautionary levels and are set far below the actual Derived Release Limits (DRL). EALs are designed to alert licensees before DRLs are reached. They are specific doses of radiation or other parameters that, if reached, may indicate a loss of control of the licensee's environmental protection program.

The release of hazardous substances is regulated by the CNSC as well as both the Ontario Ministry of the Environment, Conservation and Parks (MECP) and Environment and Climate Change Canada (ECCC) through various acts and regulations.

- The environmental protection SCA includes the following SpAs:
- Effluent and emissions control (releases);
- Environmental management system (EMS);
- Assessment and monitoring;
- Protection of the public; and
- Environmental Risk Assessment.

Compliance Verification Criteria

Licensee Documents that Require Notification of Change

Doc #	Title	Prior Notice
OPG-PROG-0005	Environmental Management System	N
OPG-POL-0021	Environmental Policy	N
N-PROC-OP-0025	Management of Environmental Monitoring Program	Y
N-STD-OP-0031	Monitoring of Nuclear and Hazardous Substances in Effluent	Y

Doc #	Title	Prior Notice
P-REP-07701-00001	Environmental Risk Assessment Report for Pickering Nuclear	Y
P-REP-03482-00006	Derived Release Limits and Environmental Action Levels for Pickering Nuclear	Y

Licensing Basis Publications

Org	Doc #	Title	Version	Effective Date
CNSC	REGDOC-2.9.1, Section 4.6	Environmental Protection: Environmental Principles, Assessments and Protection Measures	2016	Implemented
CSA Group	N288.1	Guidelines for calculating derived release limits for radioactive material in airborne and liquid effluents for normal operation of nuclear facilities	2014	Implemented
CSA Group	N288.3.4	Performance testing of nuclear air-cleaning systems at nuclear facilities	2013	Implemented
CSA Group	N288.4	Environmental monitoring program at class I nuclear facilities and uranium mines and mills	2015	Implemented
CSA Group	N288.5	Effluent monitoring programs at class I nuclear facilities and uranium mines and mills	2011	Implemented
CSA Group	N288.6	Environmental risk assessments at class I nuclear facilities and uranium mines and mills	2012	Implemented
CSA Group	N288.7	Groundwater protection programs at Class I nuclear facilities and uranium mines and mills	2015	December 31, 2020

Effluent and Emissions Control (Releases)

The licensee shall ensure effluent monitoring for nuclear and hazardous substances is designed, implemented and managed to respect applicable laws and to incorporate best practices. The effluent monitoring program shall provide for control of airborne and waterborne effluents. Effluent monitoring is a risk-informed activity, which assures quantifying of the important releases of the nuclear and hazardous substances into the environment.

OPG PWMF Effluent Monitoring Program shall be compliant with CSA N288.5-2011 *Effluent Monitoring Programs at Class I Nuclear Facilities and Uranium Mines and Mills*.

Nuclear substances – Derived Release Limits (DRL)

The licensee shall control radiological releases to ALARA, within the DRLs, and take action to investigate cause(s) and correct the cause(s) of increased releases.

If any of the individual DRLs are exceeded, or if the sum of individual releases (expressed as a fraction of the relevant DRL) exceeds unity, it indicates that the licensee is in non-compliance with the public dose limit of 1 mSv/year as per the *Radiation Protection Regulations*.

The DRLs are considered part of the licensing basis. Changes to these limits are subject to LC G.1. The DRLs for this facility are summarized in the table below. In the event of a discrepancy between the table below and the licensee documentation upon which they are based, the licensee documentation shall be considered the authoritative source (assuming that the licensee has followed its own change control process.

Release Category	Radionuclide	DRL (Bq/year)
Air	Tritium (HTO)	1.02E+17
	Iodine (mixed fission products)	2.82E+15
	Carbon-14	2.69E+15
	Noble Gases[1]	2.66E+16
	Particulate – Gross Beta-Gamma	4.25E+11
	Particulate – Gross Alpha	7.49E+10
Water	Tritium	7.87E+17
	Carbon-14	3.75E+13
	Gross Alpha	1.87E+12
	Gross Beta-Gamma	2.36E+10

[1]Noble gases DRL is in units of Bq-MeV
Note: The PWMF uses the DRLs established for the Pickering Site

These DRLs for radionuclides and radionuclide groups account for the most significant releases and are the focus of monitoring and reporting requirements.

Nuclear Substances – Environmental Action Levels (EAL)

OPG must develop and implement EALs. The EALs are considered part of the licensing basis. Changes to these limits are subject to LC G.1. The EALs for this facility are summarized in the table below. In the event of a discrepancy between the table below and the licensee documentation upon which they are based, the licensee documentation shall be considered the authoritative source (assuming that the licensee has followed its own change control process).

Further to the requirements of LC 3.2, OPG shall notify the Commission within seven days of becoming aware that an action level has been reached.

The current EALs for PWMF are given in the following table:

Release Category	Radionuclide	EALs: Gaseous Releases (Bq/week)
Air	Tritium (HTO)	2.03E+14
	Iodine	5.65E+09
	Carbon-14	5.38E+12
	Noble Gases[1]	5.32E+13
	Particulate – Gross Beta-Gamma	8.57E+08
Release Category	**Radionuclide**	**EALs: Liquid Releases (Bq/month)**
Water	Tritium (HTO)	6.29E+15
	Carbon-14	3.00E+11
	Gross Beta-Gamma	1.49E+10

[1]Noble gases EAL is in units of Bq-MeV.
Note: EAL for gross alpha is not specified since it is not a routinely monitored radionuclide group at the PNGS or PWMF because its activity is below the threshold value specified in the standard for radioactivity monitoring in effluents.
Note: The PWMF uses the EALs established for the Pickering Site.

Hazardous Substances

The licensee shall control hazardous substance releases according to the limits defined in accordance with the applicable environmental compliance approvals, provincial and other federal legislation and take action to investigate and correct the cause(s) of increased releases.

Environmental Management System (EMS)

The objective of the environmental protection policies, programs and procedures is to establish adequate provisions for protection of the environment. This shall be accomplished through an integrated set of documented activities of an environmental management system (EMS).

OPG shall implement and maintain an environmental management program to assess environmental risks associated with its nuclear activities, and to ensure these activities are conducted in such a way that adverse environmental effects are prevented or mitigated. OPG environmental management program shall be compliant with REGDOC-2.9.1, *Environmental Protection Policies, Programs and Procedures*, version 2016 section 4.6.

OPG shall ensure that all aspects of its environmental management program are effectively implemented in order to assure compliance with environmental regulatory requirements and expectations, including those set in the International Organization for Standardization 14001, *Environmental Management Systems*. OPG's EMS is registered to the ISO-14001. Having the ISO-14001certification is not part of the CNSC requirement; however it shows that a third party recognized OPG Environmental Management System as being in accordance with the standard.

Assessment and Monitoring

An environmental monitoring program consists of a risk-informed set of integrated and documented activities to sample, measure, analyze, interpret, and report the following:

- the concentration of hazardous and/or nuclear substances in environmental media to assess one or both of
  - exposure of receptors to those substances; and
  - the potential effects on human health, safety, and the environment;
- the intensity of physical stressors and/or their potential effect on human health and the environment; and
- the physical, chemical, and biological parameters of the environment normally considered in design of the EMP.

OPG Pickering's Environmental Monitoring Program is a site wide monitoring program (PNGS & PWMF) shall be compliant with CSA N288.4-2010 *Environmental Monitoring Programs at Class I Nuclear Facilities and Uranium Mines and Mills*.

<u>Groundwater monitoring</u>

The licensee shall implement the requirements of CSA Group standard N288.7-15, *Groundwater Protection Programs at Class I Nuclear Facilities and Uranium Mines and Mills* by December 31, 2020.

Protection of the public

This aspect relates to the assessment of predicted human health effects measured and potential quantities of hazardous substance in the environment (abiotic and biotic) of the Darlington NPPs. This aspect is linked to the Dose to the public SPA as well as the Environmental Risk Assessment SPA and addressed mainly under LC G.1 (Licensing Basis)

Environmental Risk Assessment

In accordance with CSA N288.4 and N288.5, the ERA establishes the basis for both the environmental monitoring program and the effluent monitoring program. The ERA shall be updated periodically with the results from the environmental and effluent monitoring programs in order to confirm the effectiveness of any additional mitigation measures needed.

OPG Pickering's ERA is a site wide ERA encompassing PNGS and PWMF and shall be compliant with CSA N288.6- 2012 *Environmental Risk Assessments at Class I Nuclear Facilities and Uranium Mines and Mills.*

Guidance

Guidance Publications

Org	Doc #	Title
CNSC	G-228	Developing and Using Action Levels
CNSC	REGDOC 2.9.1	Environmental Protection: Environmental Principles, Assessments and Protection Measures, Version 1.1
CSA	N288.2	Guidelines for Calculating the Radiological Consequences to the Public of a Release of Airborne Radioactive Material for Nuclear Reactor Accidents
CSA	N288.8	Establishing and implementing action levels for releases to the environment from nuclear facilities

It is recommended that the licensee provide to the CNSC a copy of the reports sent to the MECP and ECCC on hazardous releases.

Licence Condition 9.2 Environmental Assessment Follow-up Program

The licensee shall implement an environmental assessment follow-up program.

Preamble

In 2002, OPG identified its intent to expand the capacity of the PWMF by constructing and operating two additional storage buildings (#3 and #4) at the PWMF Phase II site. Between 2002 and 2004, a screening level Environmental Assessment (EA) under the CEAA 1992 was carried out for the proposed PWMF Phase II project.

In May 2004, the Commission issued a *Record of Proceedings, including Reasons for Decision for the PWMF Phase II EA* concluding that the project, taking into account the implementation of mitigation measures, is not likely to cause significant adverse environmental effects.

The EA process identified the need for an EA follow-up program for the PWMF Phase II project.

Compliance Verification Criteria

Licensee Documents that Require Notification of Change

Doc #	Title	Prior Notice
92896-REP-07701.8-00001	Pickering Waste Management Facility Phase II – Environmental Assessment Follow-up Plan	N

This LC requires that the ongoing environmental assessment follow-up program be completed and that progress on completion be reported annually.

Guidance

None provided.

SCA – EMERGENCY MANAGEMENT AND FIRE PROTECTION

Licence Condition 10.1 Emergency Preparedness Program

The licensee shall implement and maintain an emergency preparedness program.

Preamble

Emergency management covers emergency plans and emergency preparedness programs which exist for emergencies and for non-routine conditions. It also includes any results of exercise participation.

Compliance Verification Criteria

Licensee Documents that Require Notification of Change

Doc #	Title	Prior Notice
N-STD-RA-0036	Radioactive Materials Transportation Emergency Response Plan	N
N-PROG-RA-0001	Consolidated Nuclear Emergency Plan	Y

Licensing Basis Publications

Org	Doc #	Title	Version	Effective Date
CNSC	REGDOC-2.10.1	Nuclear Emergency Preparedness and Response, Version 2	2017	Implemented

OPG's nuclear emergency preparedness program is documented in the *Consolidated Nuclear Emergency Plan* (CNEP). The CNEP governs the Pickering site, where the PWMF is located. The CNEP deals with emergency situations that endanger the safety of onsite staff, the environment, and the public. The PNGS Emergency Response Team is the primary responder for the PWMF Phase I. For Phase II, emergency, medical, and fire response is provided by the City of Pickering, with the PNGS Emergency Response Team as the secondary responder. A Memorandum of Understanding, dated January 1, 2014 exists for the provision of emergency, medical, and fire response between the City of Pickering and OPG for PWMF Phase II.

Guidance

None provided.

Licence Condition 10.2 Fire Protection Program

The licensee shall implement and maintain a fire protection program.

Preamble

Licensees require a comprehensive fire protection program to ensure the licensed activities do not result in unreasonable risk to the health and safety of persons and to the environment due to fire and to ensure that the licensee is able to efficiently and effectively respond to emergency fire situations.

Fire protection provisions, including response, are required for the design, construction, commissioning, operation, maintenance, and decommissioning of nuclear facilities. Fire provisions cover structures, systems, and components that support the plant operation and extend within the exclusion area. External events, such as an aircraft crash or threats, are addressed by LC 12.1.

Compliance Verification Criteria

Licensee Documents that Require Notification of Change

Doc #	Title	Prior Notice
N-PROG-RA-0012	Fire Protection	Y

Licensing Basis Publications

Org	Doc #	Title	Version	Effective Date
CSA Group	N393-13	Fire protection for facilities that process, handle, or store nuclear substances	2013	Implemented
NRC	N/A	National Building Code of Canada (2015)	2015	TBD
NRC	N/A	National Fire Code of Canada (2015)	2015	TBD

To demonstrate compliance with the applicable codes and standards, the licensee shall: arrange for third party reviews of compliance with the requirements of the applicable versions of the NRC *National Building Code of Canada* and the NRC *National Fire Code of Canada* as per the intervals outlined in CSA Group standard N393-13, *Fire Protection for Facilities That Process, Handle, or Store Nuclear Substances*; have the review carried out by one or more independent external reviewers having specific expertise with such reviews; and, submit the results of the review in writing to CNSC staff.

New buildings within the PWMF Phase II licensed area shall comply with the requirements of CSA Group standard N393-13, *Fire Protection for Facilities That Process, Handle, or Store Nuclear Substances*, the NRC *National Building Code of Canada (2015)*, and the NRC *National Fire Code of Canada (2015)*.

Guidance

None provided.

SCA – WASTE MANAGEMENT

Licence Condition 11.1 Waste Management Program

The licensee shall implement and maintain a waste management program.

Preamble

The "waste management" safety and control area covers internal waste-related programs that form part of the facility's operations up to the point where the waste is removed from the facility to a separate waste management facility. This area also covers the planning for decommissioning.

CNSC Regulatory Document REGDOC-2.11, *Framework for Radioactive Waste Management and Decommissioning in Canada* defines radioactive waste as any material (liquid, gaseous or solid) that contains a radioactive "nuclear substance," as defined in section 2 of the NSCA, and which the owner has declared to be waste. In addition to containing nuclear substances, radioactive waste may also contain non-radioactive "hazardous substances," as defined in section 1 of the *General Nuclear Safety and Control Regulations*.

Compliance Verification Criteria

Licensee Documents that Require Notification of Change

Doc #	Title	Prior Notice
N-PROC-RA-0017	Segregation and Handling of Radioactive Waste	N
OPG-STD-0156	Management of Waste and Other Environmentally Regulated Materials	N
W-PROG-WM-0001	Nuclear Waste Management	Y
N-PROG-RA-0013	Radiation Protection	Y

Licensing Basis Publications

Org	Doc #	Title	Version	Effective Date
CSA Group	N292.0	General principles for the management of radioactive waste and irradiated fuel	2014	Implemented
CSA Group	N292.2	Interim dry storage of irradiated fuel	2013	Implemented
CSA Group	N292.3	Management of low- and intermediate-level radioactive waste	2014	Implemented

Org	Doc #	Title	Version	Effective Date
CSA Group	N292.0	General principles for the management of radioactive waste and irradiated fuel	2019	December 21, 2021

OPG shall characterize its waste streams and minimize the production of all wastes taking into consideration the health and safety of workers and the environment, integrate waste management programs as a key element of the facility's safety culture, and regularly audit its program to maximize its efficiency.

With respect to the storage and management of spent nuclear fuel, the waste management program should reflect the fundamental safety concerns related to criticality, exposure, heat control, containment, and retrievability. That is, the systems that are designed and operated should assure subcriticality, control of radiation exposure, assure heat removal, assure containment, and allow retrievability.

Transition

The licensee shall implement the requirements of CSA Group standard N 292.0-19, *General Principles for the Management of Radioactive Waste and Irradiated Fuel* by December 21, 2021.

Guidance

Guidance Publications

Org	Doc #	Title
CNSC	REGDOC-2.11	Framework for Radioactive Waste Management and Decommissioning in Canada

The CNSC expects that OPG will implement and audit a facility and waste stream-specific waste management program to control and minimize the volume of radioactive waste generated by the licensed activity. Inclusion of a waste management program is a key component of the licensee's safety culture.

Licence Condition 11.2 Decommissioning Plan

The licensee shall maintain a decommissioning plan.

Preamble

Paragraph 3(k) of the *Class I Nuclear Facilities Regulations* requires that a licence application contain the proposed plan for the decommissioning of the nuclear facility.

This LC requires that the licensee maintain, at this point in the life-cycle, a Preliminary Decommissioning Plan (PDP).

A PDP provides an overview of the proposed decommissioning approach that is sufficiently detailed to assure that the proposed approach is, in light of existing knowledge, technically and financially feasible, and appropriate in the interests of health, safety, security and the protection of the environment. The PDP defines areas to be decommissioned and the general structure and sequence of the principle work packages. The PDP forms the basis for establishing and maintaining a financial arrangement (financial guarantee – see LC G.3) that will assure adequate funding of the decommissioning plan.

Compliance Verification Criteria

Licensee Documents that Require Notification of Change

Doc #	Title	Prior Notice
W-PROG-WM-0003	Decommissioning Program	Y
92896-PLAN-00960-00001	Preliminary Decommissioning Plan Pickering Waste Management Facility	Y

Licensing Basis Publications

Org	Doc #	Title	Version	Effective Date
CSA Group	N294-09	Decommissioning of facilities containing nuclear substances	2009	Implemented
CSA Group	N294-19	Decommissioning of facilities containing nuclear substances	2019	See Transition

The PDP is to be kept current to reflect any changes in the site or nuclear facility. The PDP is to be revised at a minimum every five years or when required by the Commission.

The PDP was last revised and submitted to the CNSC in 2017. OPG's next scheduled submission of the PDP for the PWMF is due to the CNSC in 2022.

Transition

The licensee shall implement the requirements of CSA Group standard N 294-19, *Decommissioning of Facilities Containing Nuclear Substances* for the next scheduled PDP revision due to the CNSC in 2022.

Guidance

Guidance Publications

Org	Doc #	Title
CNSC	G-219	Decommissioning Planning for Licensed Activities
CNSC	G-206	Financial Guarantees for the Decommissioning of Licensed Activities

SCA – SECURITY

Licence Condition 12.1 Security Program

The licensee shall implement and maintain a security program.

Preamble

Nuclear security puts in place provisions to prevent, detect and stop malevolent acts, such as theft, sabotage, unauthorized access, illegal transfer or other acts involving nuclear material, other radioactive substances or their associated facilities.

Compliance Verification Criteria

Licensee Documents that Require Notification of Change

Doc #	Title	Prior Notice
92896-REP-08160-00001	Pickering Waste Management Facility Phase II Security Report	N
92896-REP-08160-00001 ADD 001	Pickering Waste Management Facility Security Report Addendum	N
N-PROG-RA-0011	Nuclear Security	Y
N-PROC-RA-0135	Cyber Security	Y
W-LIST-08161-00001	Nuclear Waste Management Cyber Essential Assets	Y

Licensing Basis Publications

Org	Doc #	Title	Version	Effective Date
CNSC	RD-363	Nuclear Security Officer Medical, Physical, and Psychological Fitness	2008	Implemented
CNSC	REGDOC-2.2.4	Fitness for Duty, Volume III: Nuclear Security Officer Medical, Physical, and Psychological Fitness	2018	December 31, 2020
CNSC	REGDOC-2.12.1	High-Security Facilities, Volume II: Criteria for Nuclear Security Systems and Devices	2018	Implemented
CNSC	REGDOC-2.12.2	Site Access Security Clearance	2013	Implemented

The licensee shall ensure the identified vital areas within the nuclear facility are protected against design basis threats and any other credible threat identified in their threat and risk assessment documentation. The prime functions that must be maintained at the PWMF to prevent unacceptable radiological consequences are those of control, and contain.

The licensee shall maintain the operation, design, and analysis provisions credited in the above assessments as required to ensure adequate engineered safety barriers for the protection against malevolent acts. The provisions for the protection against malevolent acts shall be documented as part of a managed sub program or process within the management system. The licensee shall summarize changes in design, analysis, or operation procedures that are credited for the protection against malevolent acts in the annual threat and risk assessment, and submit a copy to the Commission upon request.

The licensee shall implement measures for the purpose of preventing and detecting unauthorized entry into a protected area or inner area at a high-security site, including:

- vehicle barriers and vehicle access control points;
- perimeter intrusion detection systems and devices;
- closed-circuit video systems/devices for applications in a protected area or inner area;
- security monitoring rooms; and,
- security monitoring room systems and devices.

The licensee shall develop, implement, and maintain a cyber-security program to protect against cyber-attacks on cyber essential assets for nuclear safety, nuclear security, emergency preparedness, and safeguards functions. The cyber security program includes the following elements:

- roles and responsibilities;
- policies and procedures;
- staff training and awareness;
- overall approach to cyber-security;
- change control and configuration management;
- incident response and recovery;
- periodic self-assessments;
- security controls; and
- identification and classification of cyber essential assets.

The licensee shall file an update of the security report with the CNSC a minimum of six months before the operating licence expires. If the site security program changes at any time, it must be brought to the attention of the Director of the Nuclear Security Division at the CNSC. The changes will then be assessed to determine if the report requires an immediate update or if the update can wait until the relicensing review.

Guidance

Guidance Publications

Org	Doc #	Title
CNSC	REGDOC-2.12.3	Security of Nuclear Substances: Sealed Sources and Category I, II, and III Nuclear Material, Version 2
CSA	N290.7	Cyber Security for Nuclear Power Plants and Small Reactor Facilities
IAEA	Nuclear Security Series No. 17 Technical Guidance	Computer Security at Nuclear Facilities
IAEA	Nuclear Security Series No. 4 Technical Guidance	Engineering Safety Aspects of the Protection of Nuclear Power Plants Against Sabotage
IAEA	Nuclear Security Series No. 13 Recommendations	Nuclear Security Recommendations on Physical Protection of Nuclear Material and Nuclear Facilities

Licence Condition 12.2 Construction

The licensee shall not carry out the activities referred to in paragraph (iii) of Part IV of this licence that relate to completed construction activities in paragraph (iv) of Part IV of this licence until the submission of the proposed security arrangements and measures for the new building, or any potential modifications to the protected area that may be associated with this new building, that is acceptable to the Commission or a person authorized by the Commission.

Preamble

None provided.

Compliance Verification Criteria

The operating licence authorizes the construction and operation of additional buildings at the PWMF. This LC requires that OPG submit the proposed security arrangements and measures for the new buildings, or any potential modifications to the protected area that may be associated with the new buildings prior to receiving CNSC authorization to operate these buildings.

The Commission, or a person authorized by the Commission, will confirm that acceptable security arrangements have been submitted prior to authorizing OPG to begin operations at the new buildings.

Delegation of Authority

The statement “or a person authorized by the Commission” reflects to whom the Commission has delegated certain authority. The delegation of authority by the Commission to act as a “person authorized by the Commission” is applied to the incumbents of the following positions:

- Director, Wastes and Decommissioning Division;
- Director General, Directorate of Nuclear Cycle and Facilities Regulations; and,
- Executive Vice-President and Chief Regulatory Operations Officer, Regulatory Operations Branch.

Guidance

None provided.

SCA – SAFEGUARDS AND NON-PROLIFERATION

Licence Condition 13.1 Safeguards Program

The licensee shall implement and maintain a safeguards program.

Preamble

Canada has entered into a Safeguards Agreement and an Additional Protocol (hereafter referred to as "safeguards agreements") with the IAEA pursuant to its obligations under the *Treaty on the Non-Proliferation of Nuclear Weapons (INFCIRC/140)*. The objective of the Canada-IAEA safeguards agreements is for the IAEA to provide assurance on an annual basis to Canada and to the international community that all declared nuclear materials are in peaceful, non-explosive uses and that there is no indication of undeclared nuclear materials or activities. This conclusion confirms that Canada is in compliance with its obligations under the following Canada-IAEA safeguards agreements:

- *Agreement Between the Government of Canada and the International Atomic Energy Agency for the Application of Safeguards in Connection with the Treaty on the Non-Proliferation of Nuclear Weapons*; and,
- *Protocol Additional to the Agreement between Canada and the International Atomic Energy Agency for the Application of Safeguards in Connection with the Treaty on the Non-Proliferation of Nuclear Weapons*.

These are reproduced in *INFCIRC/164* and *INFCIRC/164/Add. 1*.

The scope of the non-proliferation program carried out under this licence is limited to tracking and reporting of foreign obligations and origins of nuclear material. Additionally, the import and export of controlled nuclear substances, equipment, and information identified in the *Nuclear Non-proliferation Import and Export Control Regulations* require separate authorization from the CNSC, consistent with section 3(2) of the *General Nuclear Safety and Control Regulations*.

Compliance Verification Criteria

Licensee Documents that Require Notification of Change

Doc #	Title	Prior Notice
N-PROG-RA-0015	Nuclear Safeguards	Y
N-STD-RA-0024	Nuclear Safeguards Implementation	Y

Licensing Basis Publications

Org	Doc #	Title	Version	Effective Date
CNSC	REGDOC-2.13.1	Safeguards and Nuclear Material Accountancy	2018	implemented
CNSC	REGDOC-2.13.1	Safeguards and Nuclear Material Accountancy	2018	October 29, 2021*

*For all aspects of the REGDOC-2.13.1 requirements related to non-fuel nuclear material inventory

The licensee shall not make changes to operation, equipment, or procedures that would affect the implementation of safeguards measures, except with the prior written approval of the Commission or a person authorized by the Commission.

With respect to the implementation of safeguards measures, changes made by the licensee to operation, equipment, or procedures as the result of agreements between the licensee, the CNSC, and the IAEA are considered routine.

If a requested change would adversely impact Canada's compliance with its safeguards agreements, CNSC staff do not have the authority to give approval, as this would violate the obligations arising from the Canada-IAEA safeguards agreement.

To avoid a potential non-compliance with REGDOC-2.13.1, section 8.1.1, when the Nuclear Material Accountancy Reporting (NMAR) e-business system is not available, OPG is to contact the CNSC International Safeguards Division (cnsc.sg.official.ccsn@canada.ca) to inform them of the issue and to seek guidance on how to fulfill reporting requirements. When OPG inventory change documents and physical-key measurement point inventory summaries are submitted using an alternative method, OPG will still be required to re-submit using the NMAR e-business system once the NMAR system becomes available. For additional information see CNSC letter e-doc 6039874.

Delegation of Authority

The statement "or a person authorized by the Commission" reflects to whom the Commission has delegated certain authority. The delegation of authority by the Commission to act as a "person authorized by the Commission" is applied to the incumbents of the following positions:

- Director, International Safeguards Division;
- DG, Directorate of Security and Safeguards; and,
- Vice-President, Technical Support Branch.

Transition

The licensee shall implement the requirements of REGDOC-2.13.1, *Safeguards and Nuclear Material Accountancy* for non-fuel nuclear material inventory, by October 29, 2021.

Guidance

None provided.

SCA – PACKAGING AND TRANSPORT

Licence Condition 14.1 Packaging and Transport Program

The licensee shall implement and maintain a packaging and transport program.

Preamble

Transport of nuclear substances is subject to the *Transport of Dangerous Goods Regulations* (TDGR) and the *Packaging and the Transport of Nuclear Substances Regulations (2015)* (PTNSR).

Compliance Verification Criteria

Licensee Documents that Require Notification of Change

Doc #	Title	Prior Notice
W-PROG-WM-0002	Radioactive Material Transportation	N
N-STD-RA-0036	Radioactive Materials Transportation Emergency Response Plan	N
N-PROG-RA-0013	Radiation Protection	Y

The licensee shall implement and maintain a packaging and transport program that will ensure compliance with the requirements of the TDGR and the PTNSR, 2015.

Guidance

None provided.

FACILITY SPECIFIC

Licence Condition 15.1 Construction Plans

The licensee shall submit an environmental management plan, a construction verification plan and the project design requirements prior to the commencement of construction activities described in paragraph (iv) of Part IV of this licence.

Preamble

None provided.

Compliance Verification Criteria

Licensing Basis Publications

Org	Doc #	Title	Version	Effective Date
CSA Group	N393-13	Fire protection for facilities that process, handle, or store nuclear substances	2013	Implemented
NRC	N/A	National Building Code of Canada (2015)	2015	TBD
NRC	N/A	National Fire Code of Canada (2015)	2015	TBD

The CNSC will confirm that both an environmental management plan and a construction verification plan are in effect prior to the commencement of construction activities as authorized in paragraph (iv) of Part IV of this licence.

The CNSC will confirm that appropriate design requirements have been developed and submitted to the CNSC prior to the onset of construction activities. These design requirements for new buildings, with the exception of storage building 4, shall comply with the NRC *National Building Code of Canada (2015),* NRC *National Fire Code of Canada (2015),* and CSA Group standard N393-13, *Fire Protection for Facilities That Process, Handle, or Store Nuclear Substances*.

Guidance

None provided.

Licence Condition 15.2 Commissioning Report

> The licensee shall not carry out the activities referred to in paragraph (iii) of Part IV of this licence that relate to completed construction activities in paragraph (iv) of Part IV of this licence until the submission of a commissioning report that is acceptable to the Commission or a person authorized by the Commission.

Preamble

None provided.

Compliance Verification Criteria

The Commission, or a person authorized by the Commission, will confirm that an acceptable commissioning report has been submitted prior to authorizing OPG to begin operations at any new buildings. Upon review and acceptance of the commissioning report, the Commission or a person authorized by the Commission, will provide formal notification that OPG is authorized to begin operations at the new building.

Delegation of Authority

The statement "or a person authorized by the Commission" reflects to whom the Commission has delegated certain authority. The delegation of authority by the Commission to act as a "person authorized by the Commission" is applied to the incumbents of the following positions:

- Director, Wastes and Decommissioning Division;
- Director General, Directorate of Nuclear Cycle and Facilities Regulations; and,
- Executive Vice-President and Chief Regulatory Operations Officer, Regulatory Operations Branch.

Guidance

None provided.

APPENDIX A: CHANGE CONTROL PROCESS

A change control process has been developed for revisions to the LCH to ensure that preparation and use of it is controlled and that all references are identified and maintained. A request to change this document can be initiated by either CNSC staff or the licensee. The change will be assessed by CNSC staff as follows:

1. The change request will be documented using the change request form;
2. The review will be coordinated by the project officer and appropriate specialists will be consulted for concurrence;
3. Approval will be obtained from the Director WDD, the DG DNCFR, or the EVP Ops, as appropriate;
4. The licensee will be consulted on the proposed changes;
5. If a dispute related to the proposed changes exists between the licensee and CNSC staff, the following process will be followed:
   - 5.1. A meeting will be scheduled between the parties;
   - 5.2. The decision and its rationale will be discussed and documented; and,
   - 5.3. If either party is not satisfied with the decision, the next stage of the process will be initiated as follows:
     - 5.3.1. A decision will be made by the Director WDD. If the decision is not satisfactory, it will be submitted to the DG DNCFR for resolution; or,
     - 5.3.2. A decision will be made by the DG DNCFR. If the decision is not satisfactory, it will be submitted to the EVP Ops for resolution; or,
     - 5.3.3. A decision will be made by the EVP Ops. If the decision is not satisfactory, it will be submitted to the Commission for resolution during a Commission Meeting. A final decision will be made by the Commission.
6. The LCH will be revised and approved by the Director WDD, the DG DNCFR, or the EVP Ops, as appropriate;
7. All changes to the LCH and any supporting information will be archived in the CNSC Records Office;
8. The document revision history will be revised in the Revision History section of the LCH; and,
9. A copy of the amended version of the LCH will be provided to the licensee and made available to CNSC staff.

Change Request Form

1. GENERAL INFORMATION			
File Plan #		**e-Doc #(s) for Change Request Form**	
Licensee	**Licence Number**	**LCH #, Rev/Version**	**Request Date**
Licensing Officer			

2. CHANGE(S) TO THE LCH			
#	**Description and Purpose**	**Proposed Change**	**References**
1	<initiator, nature, reason for change, e.g. administrative, change to a licensee doc, etc.>	<identify modifications, such as by track changes, highlighting, etc.>	<LC, page, section #, etc.>
2			

3. ASSESSMENT (text and/or e-Doc #s)			
#	**Division/Org**	**Comment**	**Disposition**
1	<division>		
	<division>		
	<licensee>		
	<division>		
2	etc.		

4. CONSENT TO MODIFY		
#	**Agreed**	**Comment**
1		
2		

Name	**Title**	**Signature**	**Date**

5. LCH DOCUMENTATION AND DISTRIBUTION		
New LCH Number	**LCH Effective Date**	**e-Doc #** (include version number)

CNSC Outgoing Notification	**e-Doc #**	**Date Sent**

APPENDIX B: DEFINITIONS AND ACRONYMS

DEFINITIONS

Accept	Accept means to indicate compliance with requirements.
Acceptable	Acceptable means to meet the requirements of CNSC staff.
Action Level	A specific dose of radiation or other parameter that, if reached, may indicate a loss of control of part of a licensee's radiation protection program and triggers a requirement for specific action to be taken (*Radiation Protection Regulations*; Glossary of CNSC Terminology).
Approval	Approval means the granting of consent by a regulatory body. Typically used to represent any form of consent from the regulatory body that does not meet the definition of authorization (IAEA Glossary).
Authorization	Authorization means the granting by a regulatory body or other governmental body of written permission for an operator to perform specified activities (IAEA Glossary): • Authorization could include, for example, licensing, certification, or registration. • The term authorization is also sometimes used to describe the document granting such permission. • Authorization is normally a more formal process than approval.
Boundary Conditions	The values of variables in a mathematical model that are assumed at the spatial bounds of the model (Glossary of CNSC Terminology).
Defence in Depth	A hierarchical deployment of different levels of diverse equipment and procedures to prevent the escalation of anticipated operational occurrences and to maintain the effectiveness of physical barriers placed between a radiation source or radioactive material and workers, members of the public or the environment, in operational states and, for some barriers, in accident conditions (Glossary of CNSC Terminology).
Design Basis	The range of conditions and events taken explicitly into account in the design of a nuclear facility, according to established criteria, such that the facility can withstand this range without exceeding authorized limits. Note: Design extension conditions are not part of the design basis (Glossary of CNSC Terminology).

Graduated Use of Force	The application of approved response force options following the RCMP incident management/intervention model or approved equivalent provincial police model (Glossary of CNSC Terminology).
Hazardous Substance	A substance, other than a nuclear substance, that is used or produced in the course of carrying on a licensed activity and that may pose a risk to the environment or the health and safety of persons (*Class II Nuclear Facilities and Prescribed Equipment Regulations*; *Uranium Mines and Mills Regulations*, Glossary of CNSC Terminology).
Licensing Basis	A set of requirements and documents for a regulated facility or activity comprising: • the regulatory requirements set out in the applicable laws and regulations; • the conditions and safety and control measures described in the facility's or activity's licence and the documents directly referenced in that licence; and, • the safety and control measures described in the licence application and the documents needed to support that licence application. (Glossary of CNSC Terminology).
Management System	The framework of processes, procedures and practices used to ensure that an organization can fulfill all tasks required to achieve its objectives safely and consistently. Note: The management system integrates all elements of an organization into one coherent system to enable all of the organization's objectives to be achieved. These elements include the structure, resources and processes. Personnel, equipment and organizational culture, as well as the documented policies and processes, are parts of the management system (Glossary of CNSC Terminology).
Notice of Non-Compliance	A notice of non-compliance (NNC) is issued when a non-compliance with the compliance CVC is confirmed through objective evidence obtained from reliable sources and based on verifiable facts. A NNC requires the licensee to take the necessary action(s) to correct the identified non-compliance and respond with one of the following: • confirmation that compliance has been restored • a timeframe for restoring compliance • a timeframe within which a corrective action plan will be submitted

Notification	The submission of information by the licensee to CNSC staff.
Order	One of the regulatory tools the CNSC uses to compel someone to do something in the interests of health, safety, the environment, national security or compliance with Canada's international obligations. Failure to comply with an order can lead to further regulatory measures, including prosecution or licensing actions (Glossary of CNSC Terminology).
Person Authorized by the Commission	Person authorized by the Commission means the Director WDD, the DG DNCFR, or EVP Ops of the CNSC, unless otherwise specified.
Qualified Staff	Trained licensee staff, deemed competent and qualified to carry out tasks associated to their respective positions.
Recommendation	A written suggestion for improvement relating to good industry practice or the promotion of good performance.
Safe Direction	Safe direction means changes in facility safety levels which would not potentially result in: • a reduction in any safety margin; • a breakdown of barriers; • an increase (in certain parameters) above accepted limits; • an increase in risk; • impairments of special safety systems; • an increase in the risk of radioactive releases or spills of hazardous substances; • injuries to workers or members of the public; • introduction of a new hazard; or, • a reduction of the facility's defence in depth provisions.
Shall	For the purpose of this handbook, "shall" is used to express a requirement, i.e., a provision that the user is obliged to satisfy in order to comply with a CSA Group standard.
Worker	A person who performs work that is referred to in a licence (Glossary of CNSC Terminology).

ACRONYMS

The following is the list of acronyms used in this document:

μCi	Microcurie
AIA	Authorized Inspection Agency
AL	Action Level
ALARA	As Low As Reasonably Achievable
ASME	American Society of Mechanical Engineers
Bq	Becquerel
CANDU	CANada Deuterium Uranium
CNEP	Consolidated Nuclear Emergency Plan
CNSC	Canadian Nuclear Safety Commission
CSA	Canadian Standards Association
cUL	Underwriters Laboratories Inc. (‘c’ meets Canadian requirements)
CVC	Compliance Verification Criteria
DG	Director General
DNCFR	Directorate of Nuclear Cycle and Facilities Regulation
DRL	Derived Release Limit
DSC	Dry Storage Container
EA	Environmental Assessment
EAL	Environmental Action Level
ECCC	Environment and Climate Change Canada
EVP Ops	Executive Vice-President and Chief Regulatory Operations Officer
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiation Protection
INFCIRC	INFormation CIRCular

LC	Licence Condition
LCH	Licence Conditions Handbook
MECP	Ministry of the Environment, Conservation and Parks
mSv	Millisievert
NFPA	National Fire Protection Association
NNC	Notice of Non-Compliance
NRC	National Research Council Canada
NSCA	*Nuclear Safety and Control Act*
ONFA	Ontario Nuclear Funds Agreement
OPG	Ontario Power Generation Inc.
PDP	Preliminary Decommissioning Plan
PIDP	Public Information and Disclosure Program
PNGS	Pickering Nuclear Generating Station
PWMF	Pickering Waste Management Facility
SCA	Safety and Control Area
SSC	Systems, Structures, and Components
WDD	Wastes and Decommissioning Division
WFOL	Waste Facility Operating Licence

APPENDIX C: LIST OF LICENSING BASIS PUBLICATIONS

Doc #	Title	Version	LC
American Society of Mechanical Engineers Documents			
B31.1	Power Piping	2010	5.2
Canadian Nuclear Safety Commission Documents			
RD-363	Nuclear Security Officer Medical, Physical, and Psychological Fitness	2008	12.1
RD/GD-99.3	Public Information and Disclosure	2012	G.4 3.2
REGDOC-2.1.2	Safety Culture	2018	2.1
REGDOC-2.2.2	Personnel Training	2014	2.2
REGDOC-2.2.4	Fitness for Duty: Managing Worker Fatigue	2017	2.1
REGDOC-2.2.4	Fitness for Duty, Volume II: Managing Alcohol and Drug Use, version 2	2017	2.1
REGDOC-2.2.4	Fitness for Duty, Volume III: Nuclear Security Officer Medical, Physical, and Psychological Fitness	2018	12.1
REGDOC-2.6.3	Aging Management	2014	6.1
REGDOC-2.9.1	Environmental Protection: Environmental Principles, Assessments and Protection Measures	Section 4.6, 2016	9.1
REGDOC-2.10.1	Nuclear Emergency Preparedness and Response, Version 2	2017	10.1
REGDOC-2.12.2	Site Access Security Clearance	2013	12.1
REGDOC-2.12.3	Security of Nuclear Substances – Sealed Sources	2013	12.1
REGDOC-2.13.1	Safeguards and Nuclear Material Accountancy	2018	13.1

Doc #	Title	Version	LC
REGDOC 3.1.2	Reporting Requirements, Volume 1: Non-Power Reactor Class I Nuclear Facilities and Uranium Mines and Mills	2018	3.2
REGDOC 3.2.1	Public Information and Disclosure	2018	G.4 3.2
Canadian Standards Association Group Documents			
B51	Boiler, pressure vessel, and pressure piping code	2009 and Update No. 1	5.2
N285.0	General requirements for pressure-retaining systems and components in CANDU nuclear power plants	2008 and Updates No. 1 and 2; and Annex N of N285.0-12 and Update No. 1	5.2
N286	Management system requirements for nuclear facilities	2012	1.1
N286.7	Quality assurance of analytical, scientific, and design computer programs	2016	4.1
N288.1	Guidelines for calculating derived release limits for radioactive material in airborne and liquid effluents for normal operation of nuclear facilities	2014	9.1
N288.3.4	Performance testing of nuclear air-cleaning systems at nuclear facilities	2013	9.1
N288.4	Environmental monitoring program at class I nuclear facilities and uranium mines and mills	2015	9.1
N288.5	Effluent monitoring programs at class I nuclear facilities and uranium mines and mills	2011	9.1
N288.6	Environmental risk assessments at class I nuclear facilities and uranium mines and mills	2012	9.1
N288.7	Groundwater protection programs at Class I nuclear facilities and uranium mines and mills	2015	9.1

Doc #	Title	Version	LC
N292.0	General principles for the management of radioactive waste and irradiated fuel	2014	4.1 11.1
N292.2	Interim dry storage of irradiated fuel	2013	4.1 11.1
N292.3	Management of low- and intermediate-level radioactive waste	2014	4.1 11.1
N294	Decommissioning of facilities containing nuclear substances	2009	G.3 11.2
N393	Fire protection for facilities that process, handle, or store nuclear substances	2013	5.1 10.2 15.1
National Fire Protection Association			
NFPA-20	Standard for the Installation of Stationary Pumps for Fire Protection	2010 and Amendment 1 and Amendment 2	5.2
NFPA-24	Standard for the Installation of Private Fire Service Mains and Their Appurtenances	2010	5.2
National Research Council Canada Documents			
N/A	National Building Code of Canada	2015	5.1 10.2 15.1
N/A	National Fire Code of Canada	2015	5.1 10.2 15.1

APPENDIX D: LIST OF LICENSEE DOCUMENTS THAT REQUIRE NOTIFICATION OF CHANGE

Doc #	Title	Prior Notice	LC
N/A	CNSC Financial Security and ONFA Access Agreement between OPG, the Province of Ontario and the CNSC effective January 1, 2018	Y Requires CNSC acceptance of change	G.3
00104-PLAN-79171-00001	Used Fuel Dry Storage Container Aging Management Plan	Y	6.1
00104-PLAN-79171-00002	Ontario Power Generation Dry Storage Container – Base (Underside) Inspection Plan	Y	6.1
92896-CORR-00531-01031	Application for Renewal of Pickering Waste Management Facility Operating Licence	N	G.1 3.1
92896-CORR-00531-01075	Additional Information to Support the Application for Renewal of Pickering Waste Management Facility Operating Licence	N	G.1 3.1
92896-OPP-01911.1-00001	Operating Policies and Principles, Pickering Waste Management Facility	Y	3.1 3.2
92896-PLAN-00960-00001	Preliminary Decommissioning Plan Pickering Waste Management Facility	Y	11.2
92896-REP-07701.8-00001	Pickering Waste Management Facility Phase II – Environmental Assessment Follow-up Plan	N	9.2
92896-REP-08160-00001	Pickering Waste Management Facility Phase II Security Report	N	12.1
92896-REP-08160-00001 ADD 001	Pickering Waste Management Facility Security Report Addendum	N	12.1
92896-SR-01320-10002	Pickering Waste Management Facility – Safety Report	Y	3.1 4.1
N-CHAR-AS-0002	Nuclear Management System	Y	1.1
N-CORR-00531-06752 N-CORR-00531-19076	Authorized Inspection Agency Service Agreement	Y	5.2
N-LIST-00531-10003	Index to OPG Pressure Boundary Program Elements	N	5.2

Doc #	Title	Prior Notice	LC
N-MAN-01913.11-10000	Pressure Boundary Program Manual	N	5.2
N-POL-0001	Nuclear Safety Policy	N	1.1
N-PROC-AS-0077	Nuclear Safety Culture Assessment	N	1.1
N-PROC-MP-0040	System and Item Classification	Y	5.2
N-PROC-MP-0082	Design Registration	Y	5.2
N-PROC-OP-0025	Management of Environmental Monitoring Program	Y	9.1
N-PROC-OP-0043	Waste Management	N	11.1
N-PROC-OP-0047	Hours Of Work Limits And Managing Worker Fatigue	Y	2.1
N-PROC-RA-0017	Segregation and Handling of Radioactive Waste	N	11.1
N-PROC-RA-0020	Preliminary Event Notification	N	3.2
N-PROC-RA-0135	Cyber Security	Y	12.1
N-PROC-TR-0008	Systematic Approach to Training	N	2.2
N-PROG-AS-0002	Human Performance	N	2.1
N-PROG-MA-0026	Equipment Reliability	N	6.1
N-PROG-MP-0001	Engineering Change Control	N	5.1
N-PROG-MP-0004	Pressure Boundary	Y	5.2
N-PROG-MP-0008	Integrated Aging Management	N	6.1
N-PROG-MP-0009	Design Management	N	5.1 6.1
N-PROG-MP-0014	Reactor Safety Program	N	4.1
N-PROG-RA-0001	Consolidated Nuclear Emergency Plan	Y	10.1
N-PROG-RA-0002	Conduct of Regulatory Affairs	N	3.2
N-PROG-RA-0003	Performance Improvement	N	3.2
N-PROG-RA-0011	Nuclear Security	Y	12.1

Doc #	Title	Prior Notice	LC
N-PROG-RA-0012	Fire Protection	Y	10.2
N-PROG-RA-0013	Radiation Protection	Y	7.1 11.1 14.1
N-PROG-RA-0015	Nuclear Safeguards	Y	13.1
N-PROG-TR-0005	Training	N	2.2
N-REP-03420-10011	Occupational Radiation Protection Action Levels for Nuclear Waste Management Facilities	Y	7.1
N-STD-AS-0013	Nuclear Public Information Disclosure	N	G.4
N-STD-AS-0020	Nuclear Management Systems Organizations	N	1.1
N-STD-AS-0023	Nuclear Safety Oversight	N	1.1
N-STD-MP-0027	Configuration Management	N	5.1
N-STD-MP-0028	Conduct of Engineering	N	5.1 6.1
N-STD-OP-0031	Monitoring of Nuclear and Hazardous Substances in Effluent	Y	9.1
N-STD-RA-0024	Nuclear Safeguards Implementation	Y	13.1
N-STD-RA-0036	Radioactive Materials Transportation Emergency Response Plan	N	10.1 14.1
P-REP-03482-00006	Derived Release Limits and Environmental Action Levels for Pickering Nuclear	Y	9.1
P-REP-07701-00001	Environmental Risk Assessment Report for Pickering Nuclear	Y	9.1
OPG-POL-0001	Employee Health and Safety Policy	N	8.1
OPG-POL-0021	Environmental Policy	N	9.1
OPG-PROC-0019	Records and Document Management	N	G.2
OPG-PROG-0001	Information Management	N	G.2
OPG-PROG-0005	Environmental Management System	N	9.1

Doc #	Title	Prior Notice	LC
OPG-PROG-0009	Items and Services Management	N	1.1
OPG-PROG-0010	Health and Safety Management System Program	N	1.1 8.1
W-LIST-08161-00001	Nuclear Waste Management Cyber Essential Assets	Y	12.1
W-PROG-WM-0001	Nuclear Waste Management	Y	1.1 3.1 6.1 10.1 11.1
W-PROG-WM-0002	Radioactive Material Transportation	N	14.1
W-PROG-WM-0003	Decommissioning Program	Y	11.2

APPENDIX E: LIST OF GUIDANCE PUBLICATIONS

Doc #	Title	Version	LC
Canadian Nuclear Safety Commission Documents			
G-129	Keeping Radiation Exposures and Doses 'As Low As Reasonably Achievable'	2004	7.1
G-206	Financial Guarantees for the Decommissioning of Licensed Activities	2000	G.3 11.2
G-219	Decommissioning Planning for Licensed Activities	2000	G.3 11.2
G-228	Developing and Using Action Levels	2001	7.1 9.1
G-276	Human Factors Engineering Program Plans	2003	2.1 5.1
G-278	Human Factors Verification and Validation Plans	2003	2.1 5.1
REGDOC-2.1.1	Management Systems	2019	1.1
REGDOC-2.2.1	Human Factors	2019	2.1
REGDOC-2.2.2	Personnel Training (Section 5)	2016	2.2
REGDOC-2.2.5	Minimum Staff Complement	2019	2.1
REGDOC-2.6.2	Maintenance Programs for Nuclear Power Plants	2017	6.1
REGDOC-2.9.1	Environmental Protection: Environmental Principles, Assessments and Protection Measures, Version 1.1	2017	9.1
REGDOC-2.11	Framework for Radioactive Waste Management and Decommissioning in Canada	2018	11.1
REGDOC-2.12.3	Security of Nuclear Substances: Sealed Sources and Category I, II, and III Nuclear Material, Version 2	2019	12.1

Doc #	Title	Version	LC
Canadian Standards Association Group Documents			
N288.2	Guidelines for Calculating the Radiological Consequences to the Public of a Release of Airborne Radioactive Material for Nuclear Reactor Accidents	1991 (R2013)	9.1
N288.8	Establishing and implementing action levels for releases to the environment from nuclear facilities	2017	9.1
N290.7	Cyber Security for Nuclear Power Plants and Small Reactor Facilities	2014	12.1
N290.12	Human factors in design for nuclear power plants	2014	5.1
N291	Requirements for safety-related structures for nuclear power plants	2015	5.1 6.1
International Atomic Energy Agency Documents			
Nuclear Security Series No. 4 Technical Guidance	Engineering Safety Aspects of the Protection of Nuclear Power Plants Against Sabotage	2007	12.1
Nuclear Security Series No. 13 Recommendations	Nuclear Security Recommendations on Physical Protection of Nuclear Material and Nuclear Facilities	Revision 5	12.1
Nuclear Security Series No. 17 Technical Guidance	Computer Security at Nuclear Facilities	2011	12.1
SSG-15	Storage of Spent Nuclear Fuel	2012	6.1
Ontario Power Generation			
N-REF-01913.11-10001	Temporary Leak Maintenance by Leak Mitigation Process	2019	5.2

ONTARIO POWER GENERATION	Report	Public Information	
		Document Number: N-REP-07701-00007	Usage Classification: Information
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Title: Environmental Risk Assessment Report for Pickering Nuclear			

Environmental Risk Assessment Report for Pickering Nuclear

P-REP-07701-00007 R001
2023-03-31

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Public Information

Accepted By: Cammie Cheng — Mar 31, 2023

Cammie Cheng for Raphael McCalla, Director, Nuclear Environment — Date

ENVIRONMENTAL RISK ASSESSMENT REPORT FOR PICKERING NUCLEAR

P-REP-07701-00007 R001

REPORT PREPARED FOR:

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Ref. 21-2827
31 March 2023

Ecometrix | Environmental INTELLIGENCE

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	

<u>Results of the EcoRA</u>

<u>Non-radiological EcoRA</u>

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.

<u>Radiological EcoRA</u>

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:

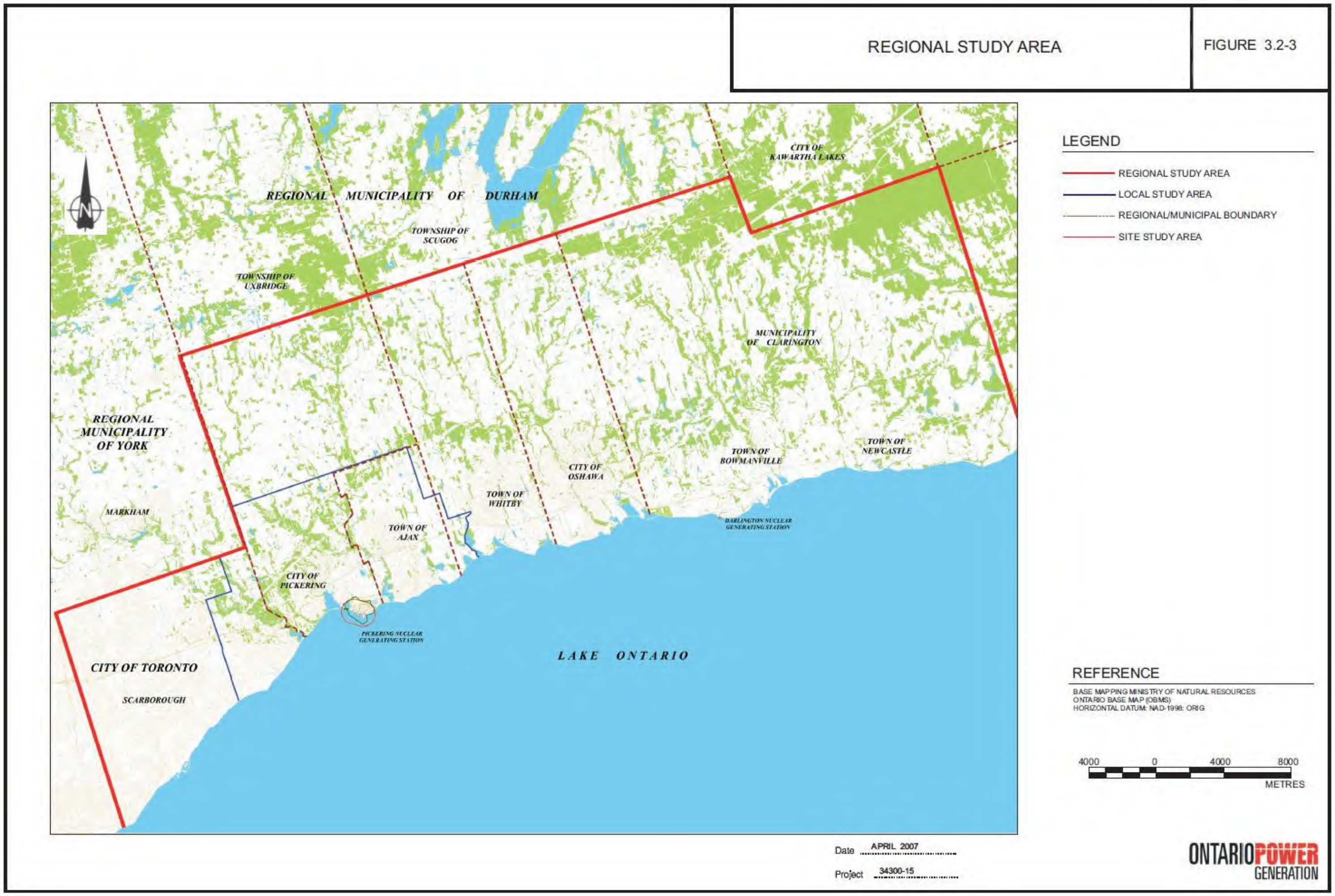
- To evaluate the risk to relevant human and ecological receptors resulting from exposure to contaminants and stressors related to the PN site and its activities.
- To recommend potential further monitoring or assessment as needed based on the results of the ERA.

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).

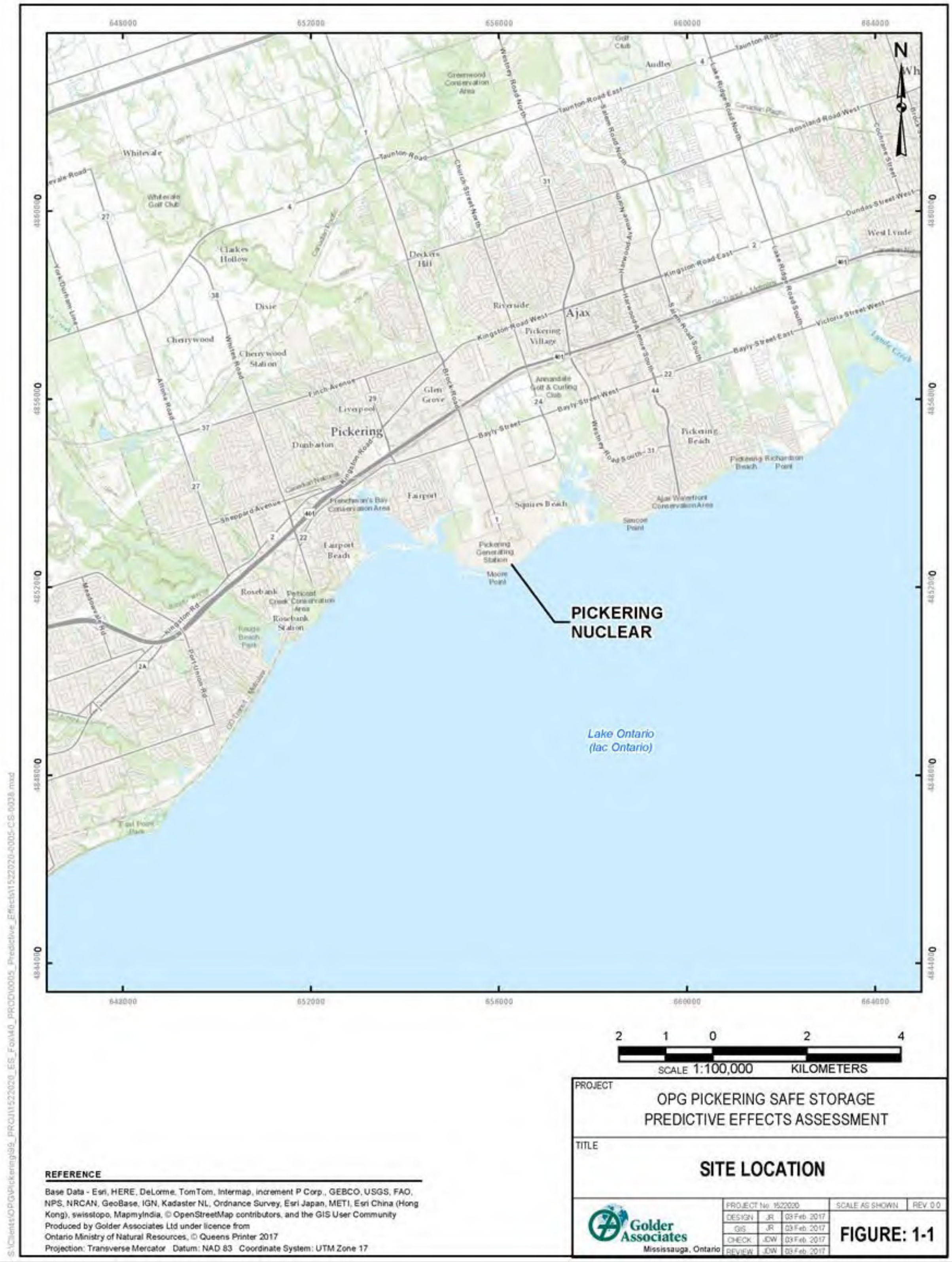
Table 2.1: In-Service Dates for PN U1-4 and U5-8

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

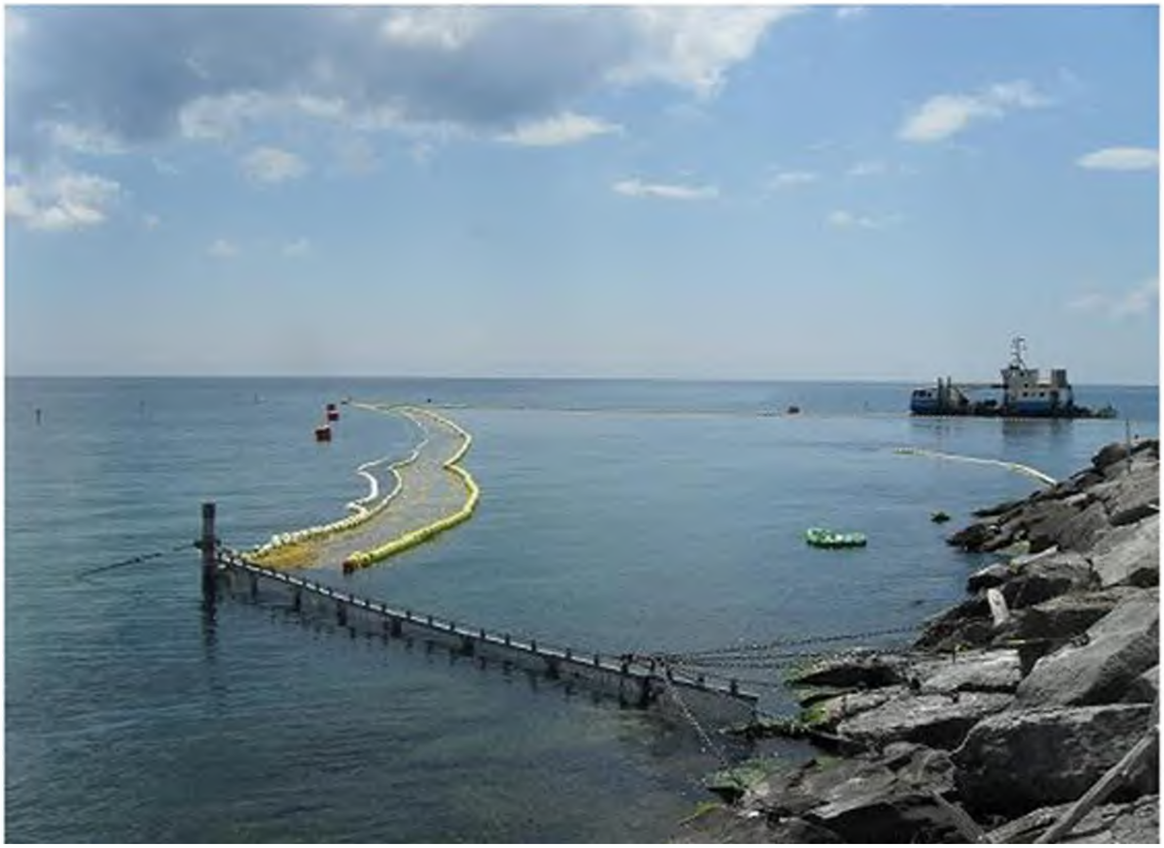
The East Landfill is an on-site waste disposal site established in 1971 to receive excavation and construction waste during the construction of PN U5-8. The landfill is located at the south-east corner of the intersection of Brock Road and Montgomery Park Road within PN's property boundary. A smaller 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

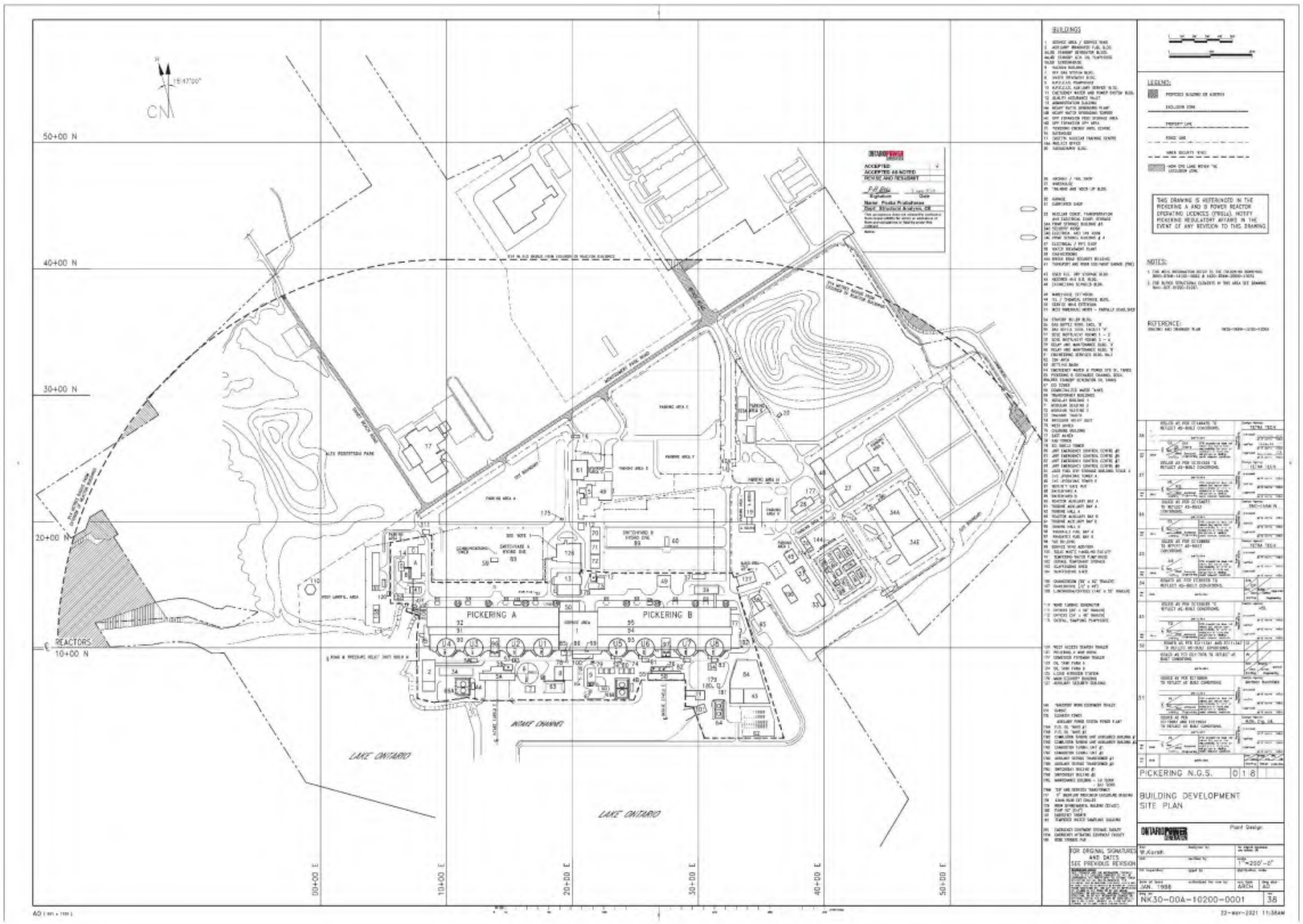


Figure 2.4: Pickering Nuclear Generation Station Site Plan

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).

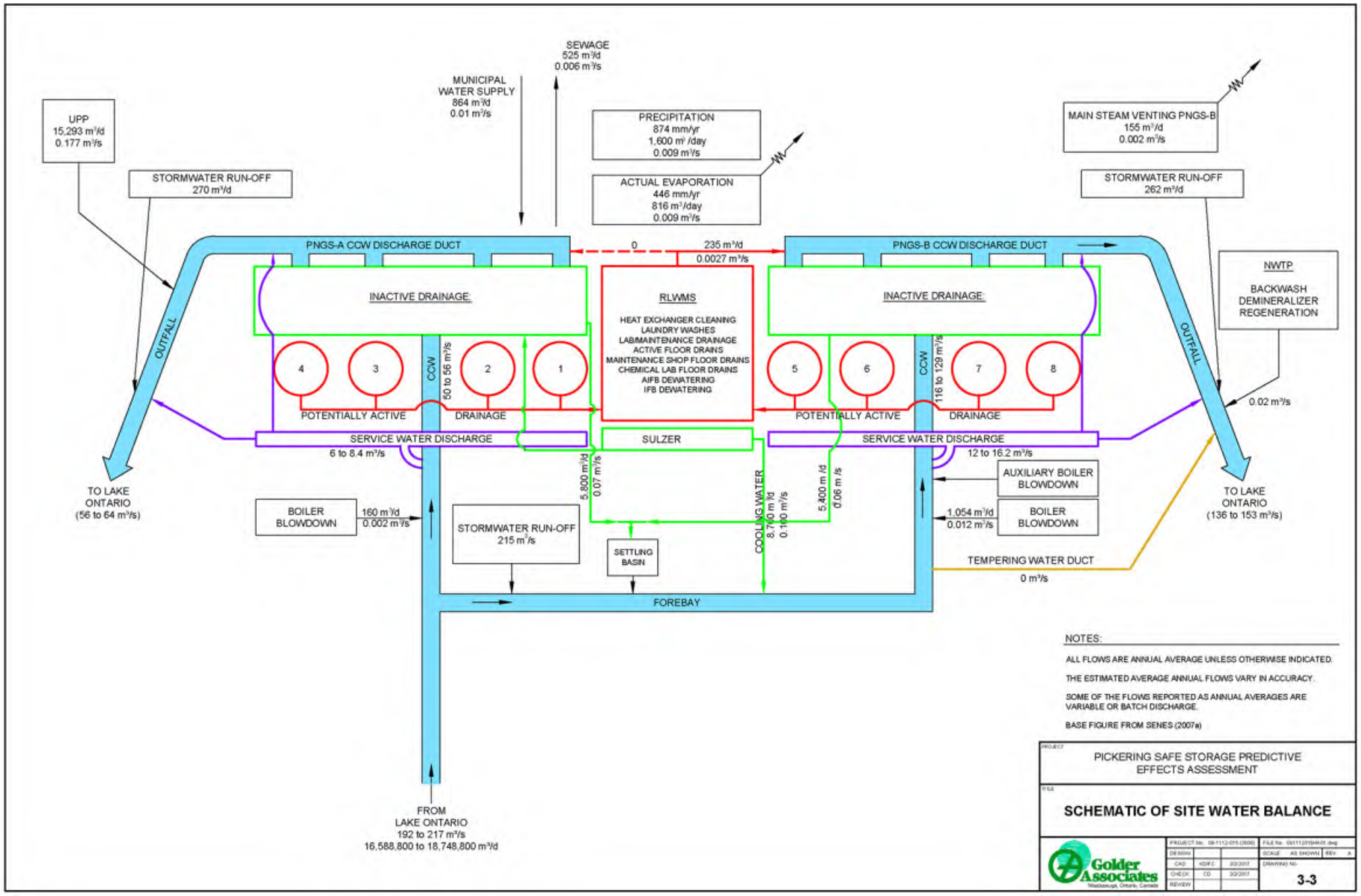
Active drainage generated from activities at the PWMF Phase I site is directed to two underground active liquid sumps and transferred via sump pumps to two holding tanks located in the Phase I workshop. Active drainage in the Phase I workshop consists of air conditioning condensate, wash water from janitorial 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).

Other discharges

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.

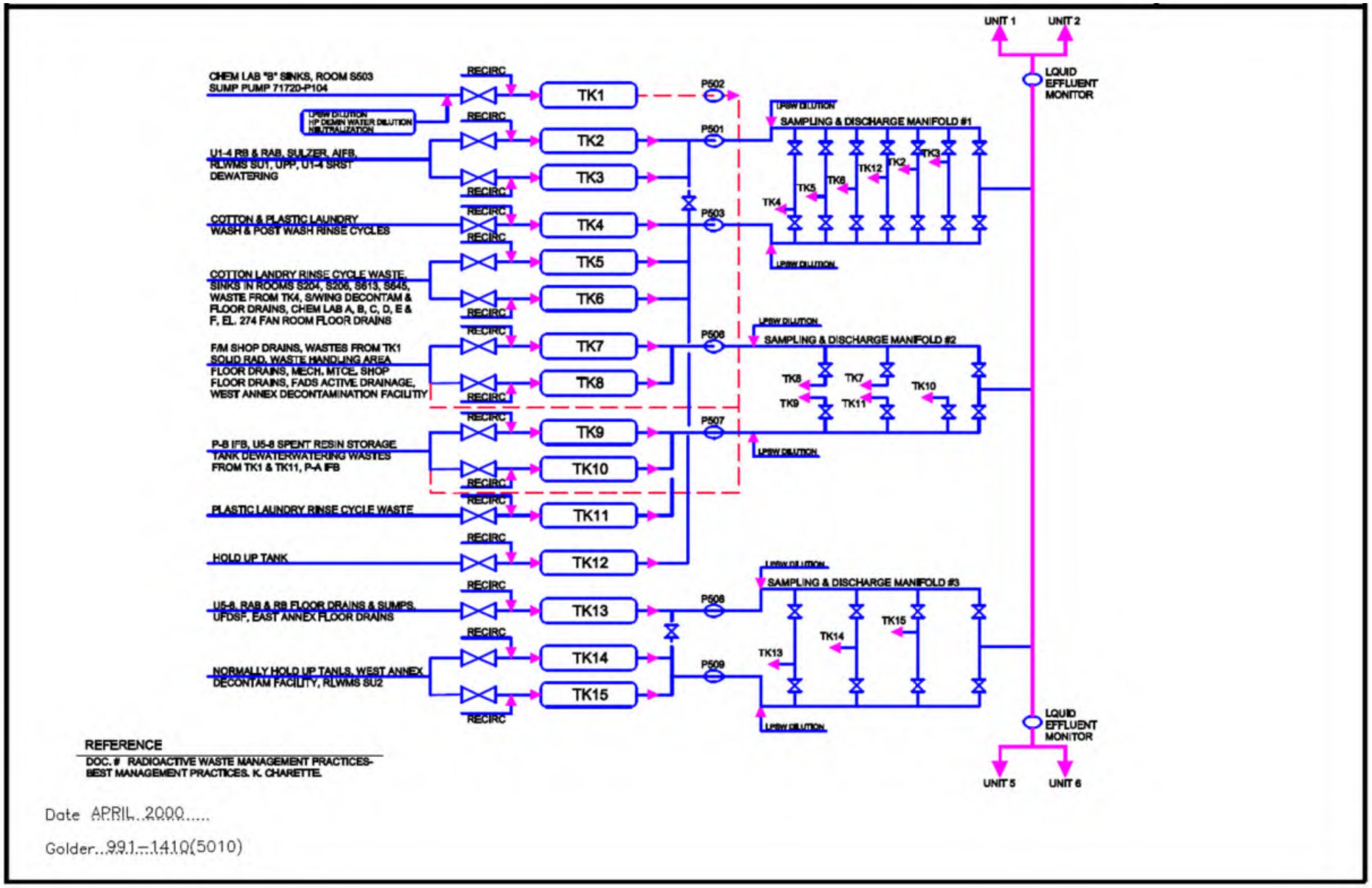
Active liquid waste from the PWMF is pumped to the RLWMS for processing. Active drainage from the PWMF consists of air conditioning condensate, wash water from janitorial activities, or precipitation ingress during DSC transfers that collects in the DSC processing building floor drains. A simplified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

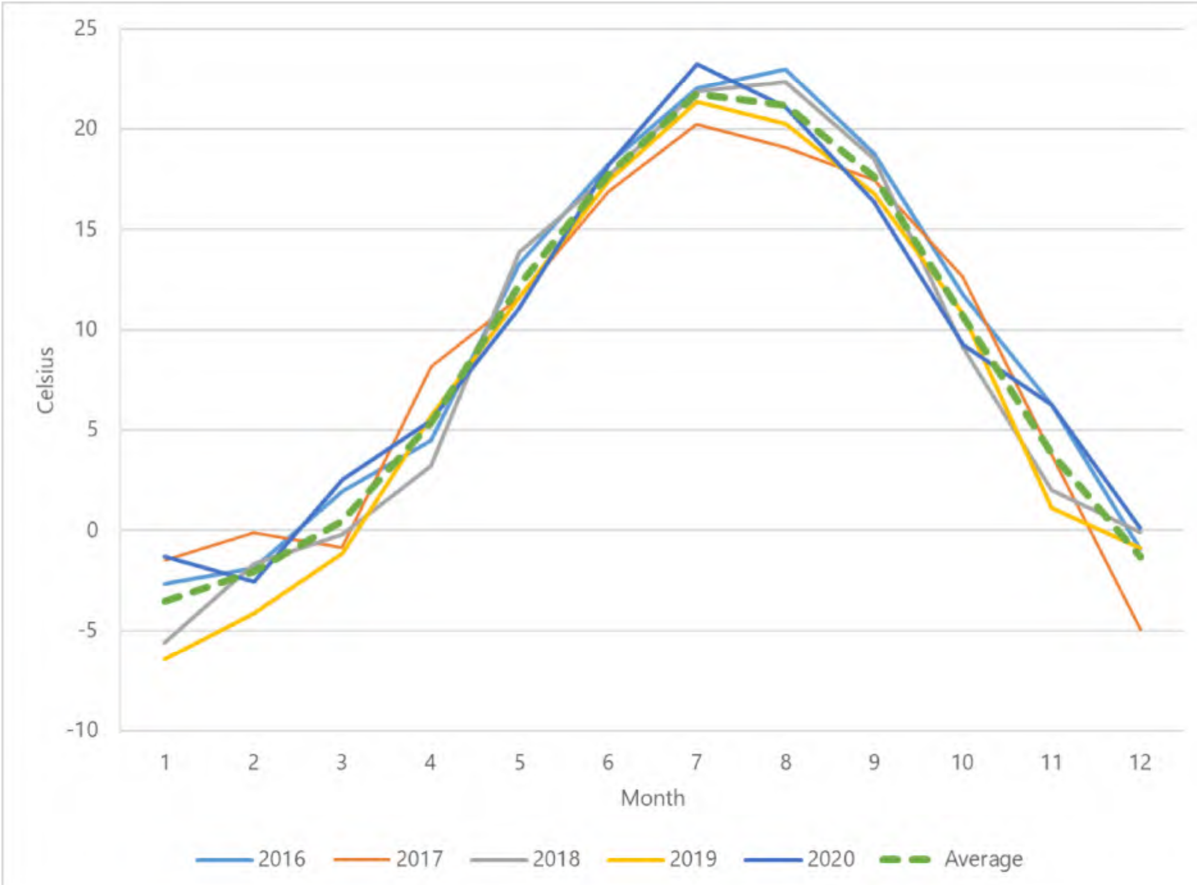


Figure 2.7 Average Monthly Air Temperatures Reported at the PN Meteorological Station (2016-2020)

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.

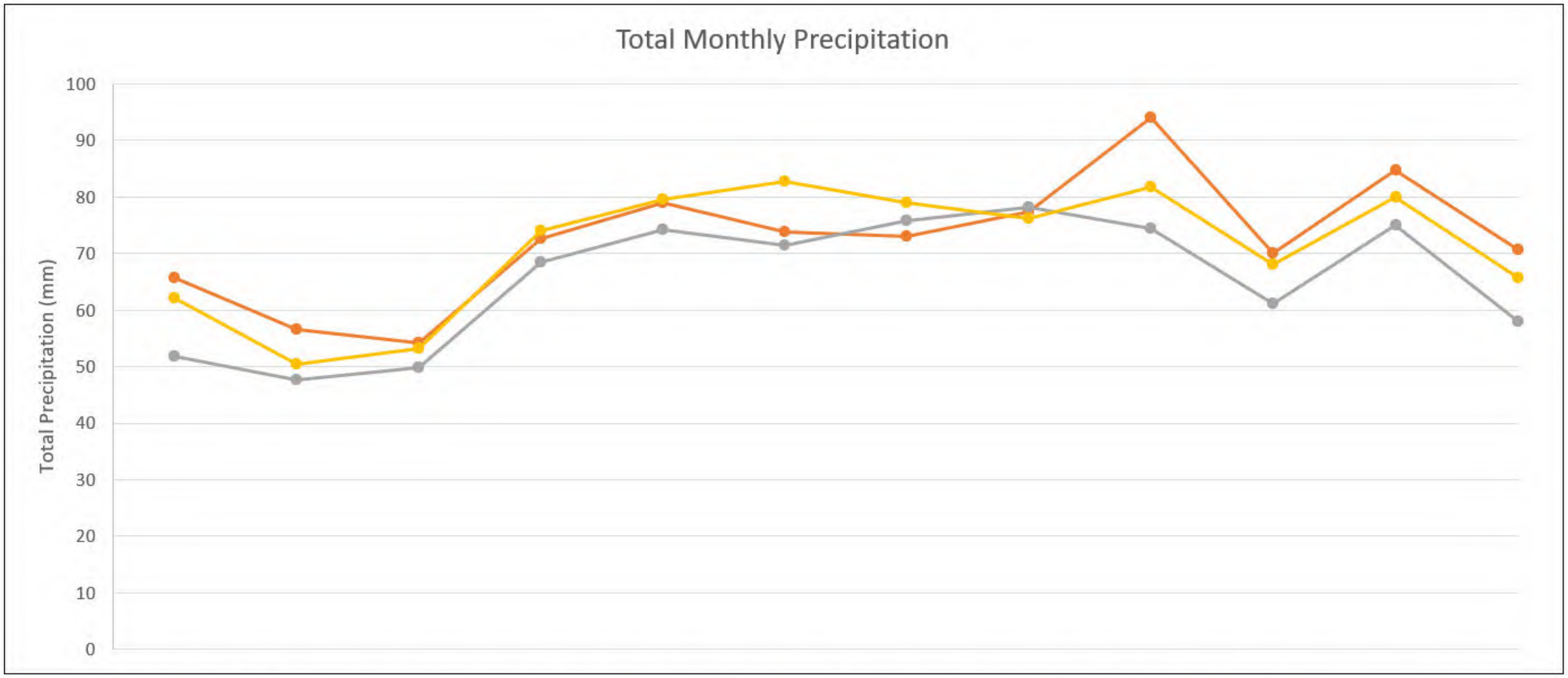
Total monthly precipitation normals from Oshawa are compared to the most recent precipitation normals (1981 to 2010), for the Pearson International Airport (TOR) and Toronto Buttonville Airport (BUT) climate stations (ECCC, 2020). The TOR is located approximately 35 km west – south – west of the PN site,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

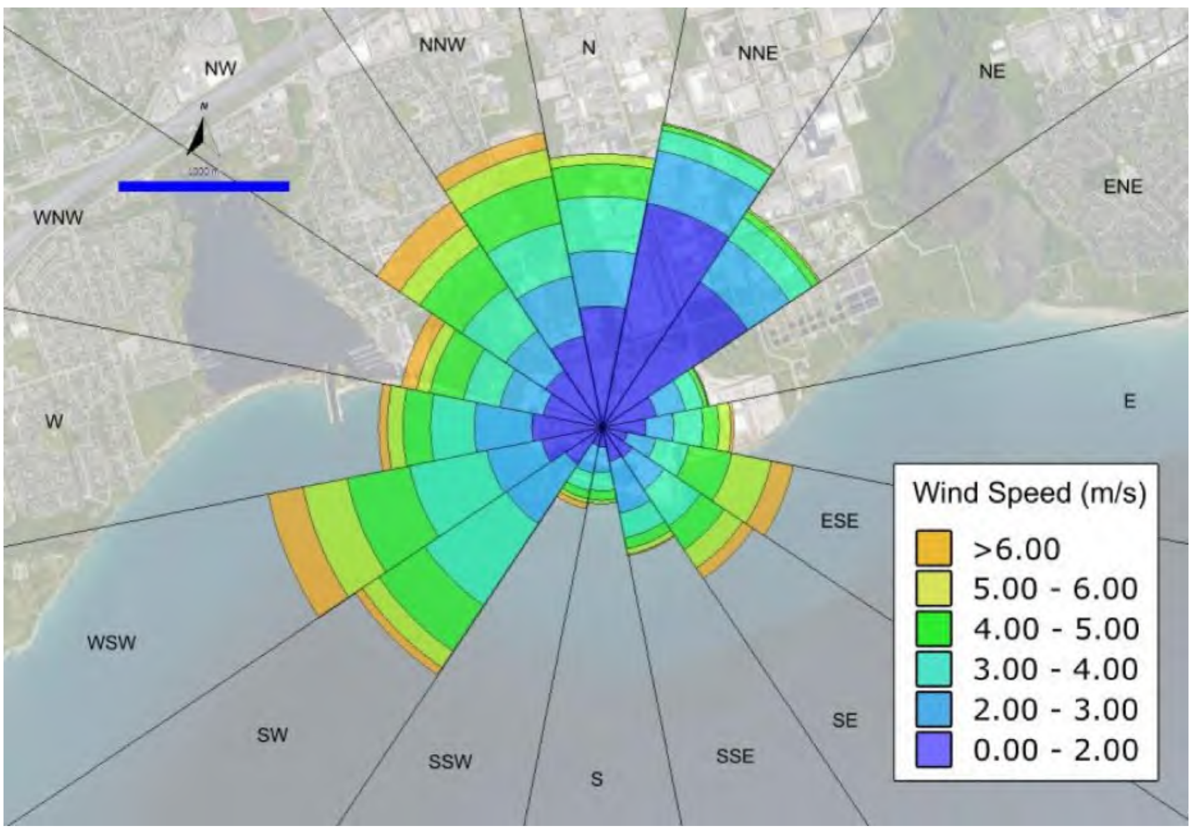
BUT – Toronto Buttonville Airport, 1981-2010 (Government of Canada, 2021)

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

2.3.1.3 Wind

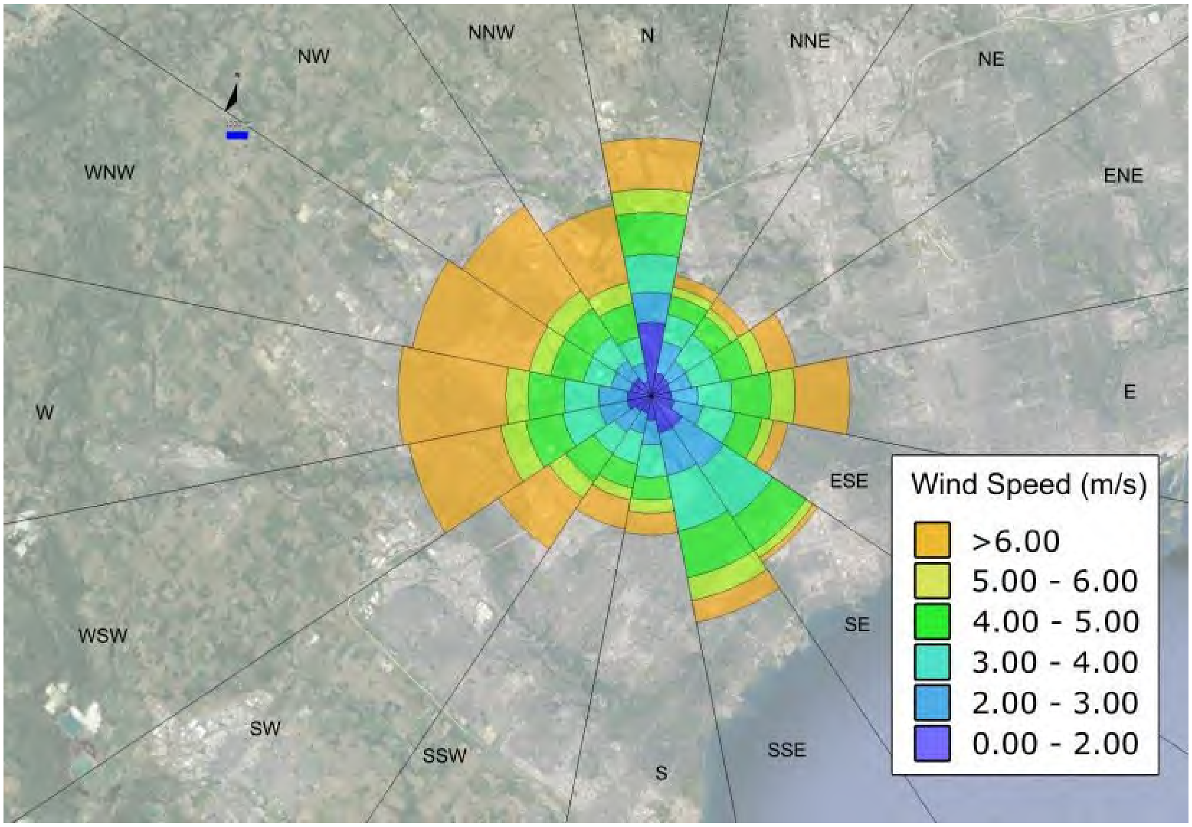
The most recent consecutive five-year period of reliable wind data is 2016 to 2020. The data are summarized as a windrose diagram in Figure 2.9 (Note: Wind is blowing from the indicated direction). The 5-year average meteorological data from 2016 to 2020 are expected to be representative of current average 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.

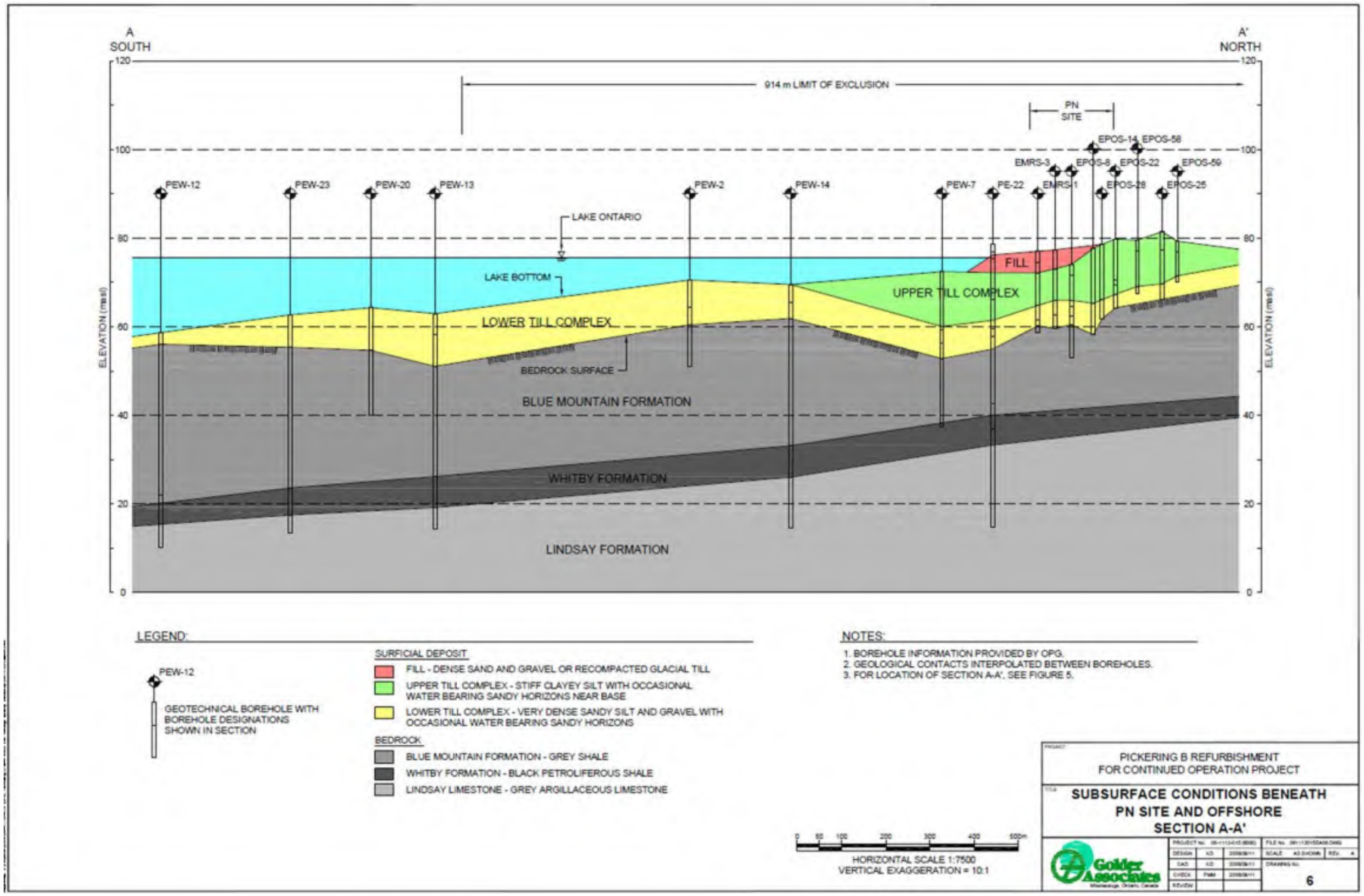
Investigations conducted in advance of the construction of PN U1-4 and U5-8 indicate that the pre-construction subsoils in the area of the existing plant generally consisted of glacial silt and sand tills up to 24 m thick overlying shale bedrock. Currently, the soil sequence overlying the bedrock beneath 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.

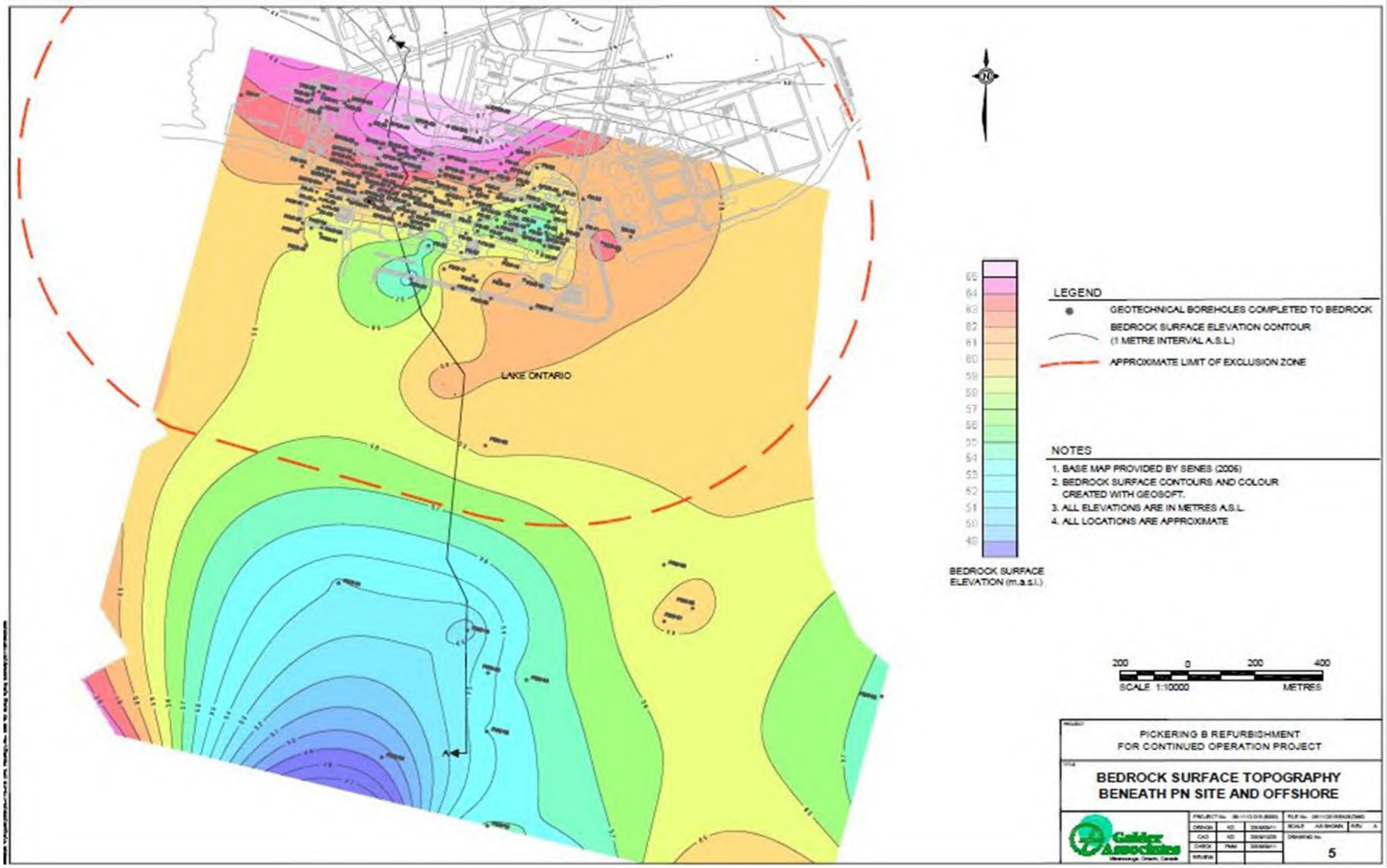
2.3.2.1 Soil Type

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.

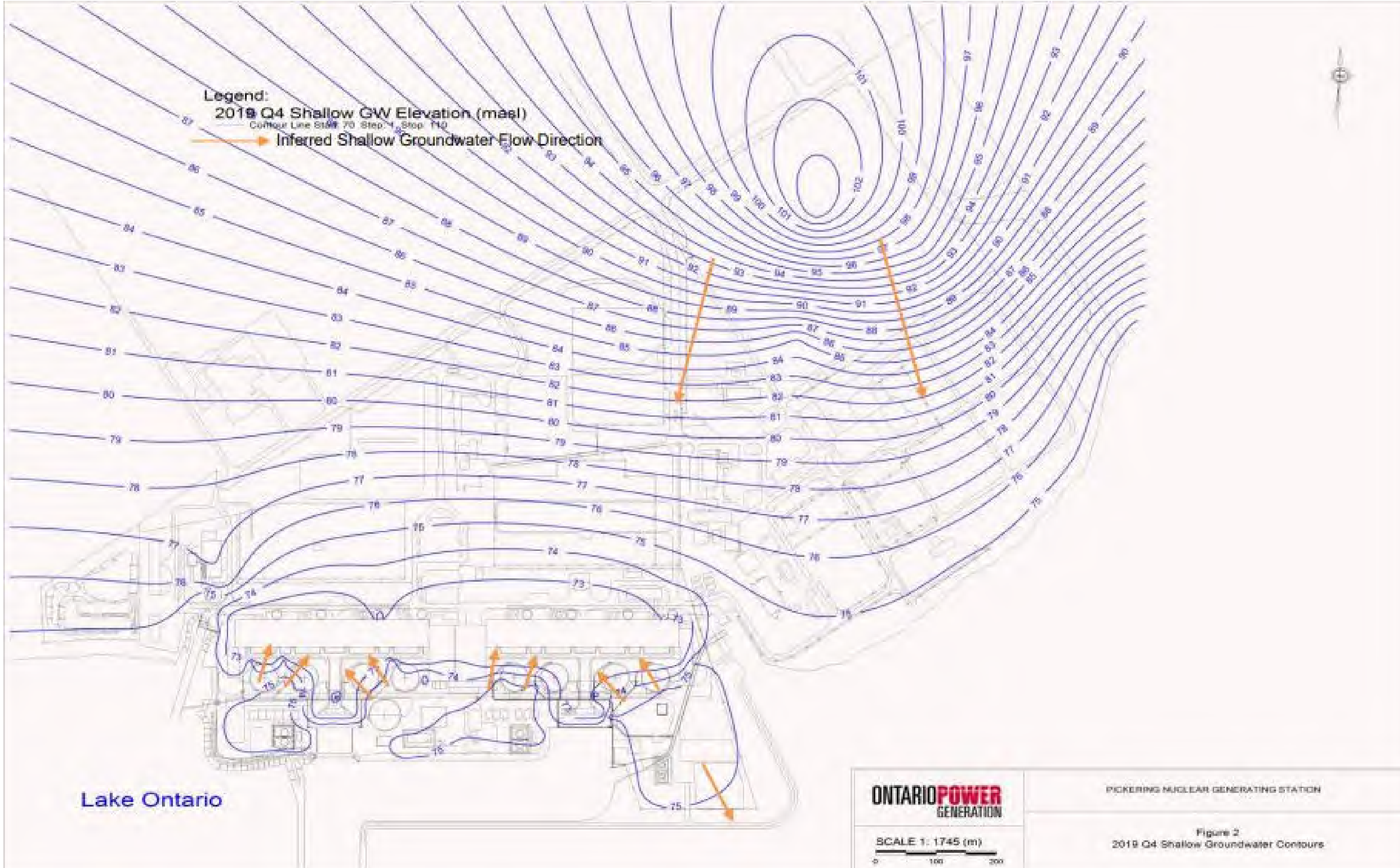
A groundwater divide appears to be present along the northern portion of the PN site that generally runs parallel to Montgomery Park Road. Shallow groundwater north of the Montgomery Park Road flows west towards Frenchman's Bay. In the area south of Montgomery Park Road the direction of groundwater flow 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.

<u>Intermediate Groundwater</u>

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.

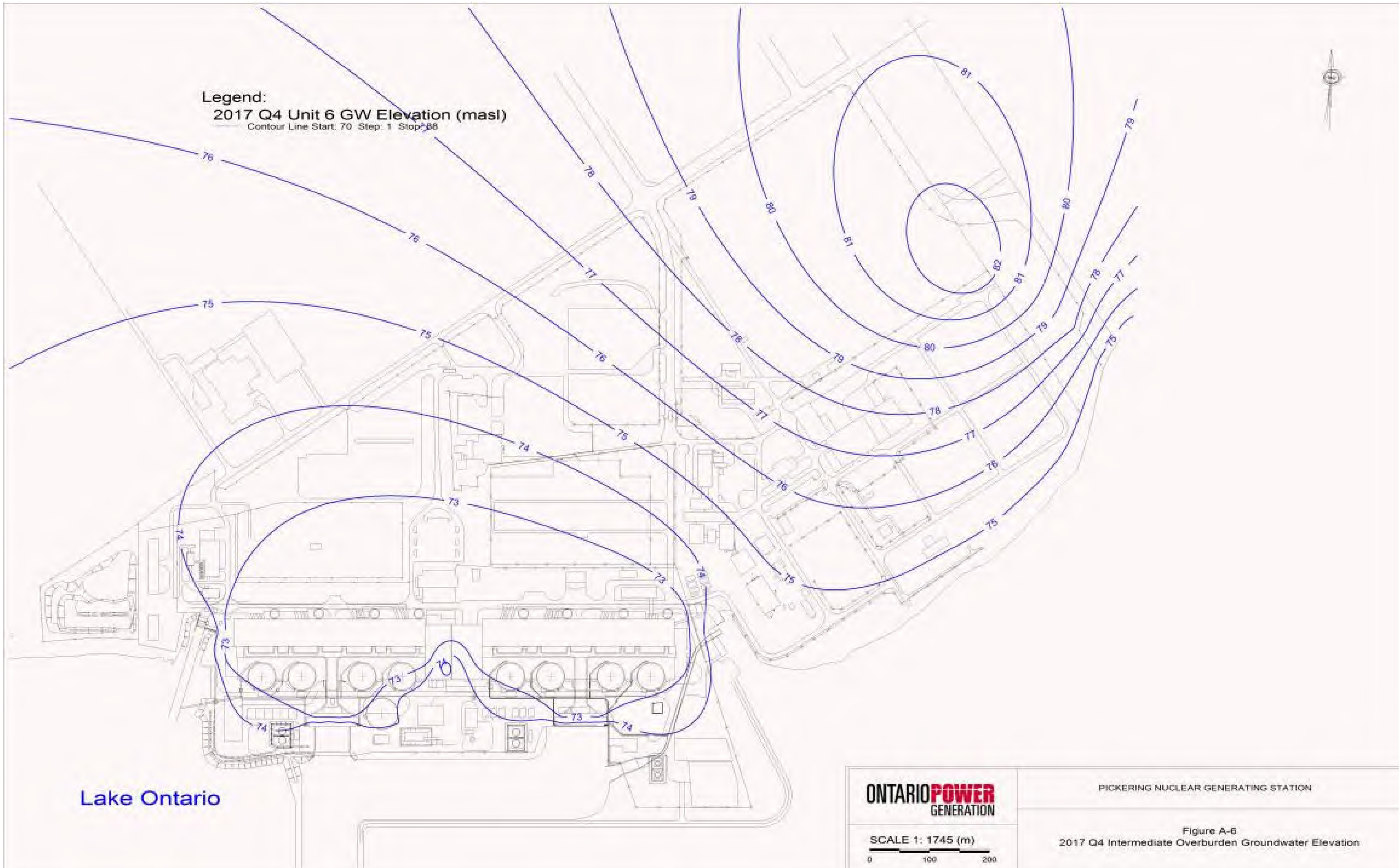
<u>Deeper Groundwater</u>

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

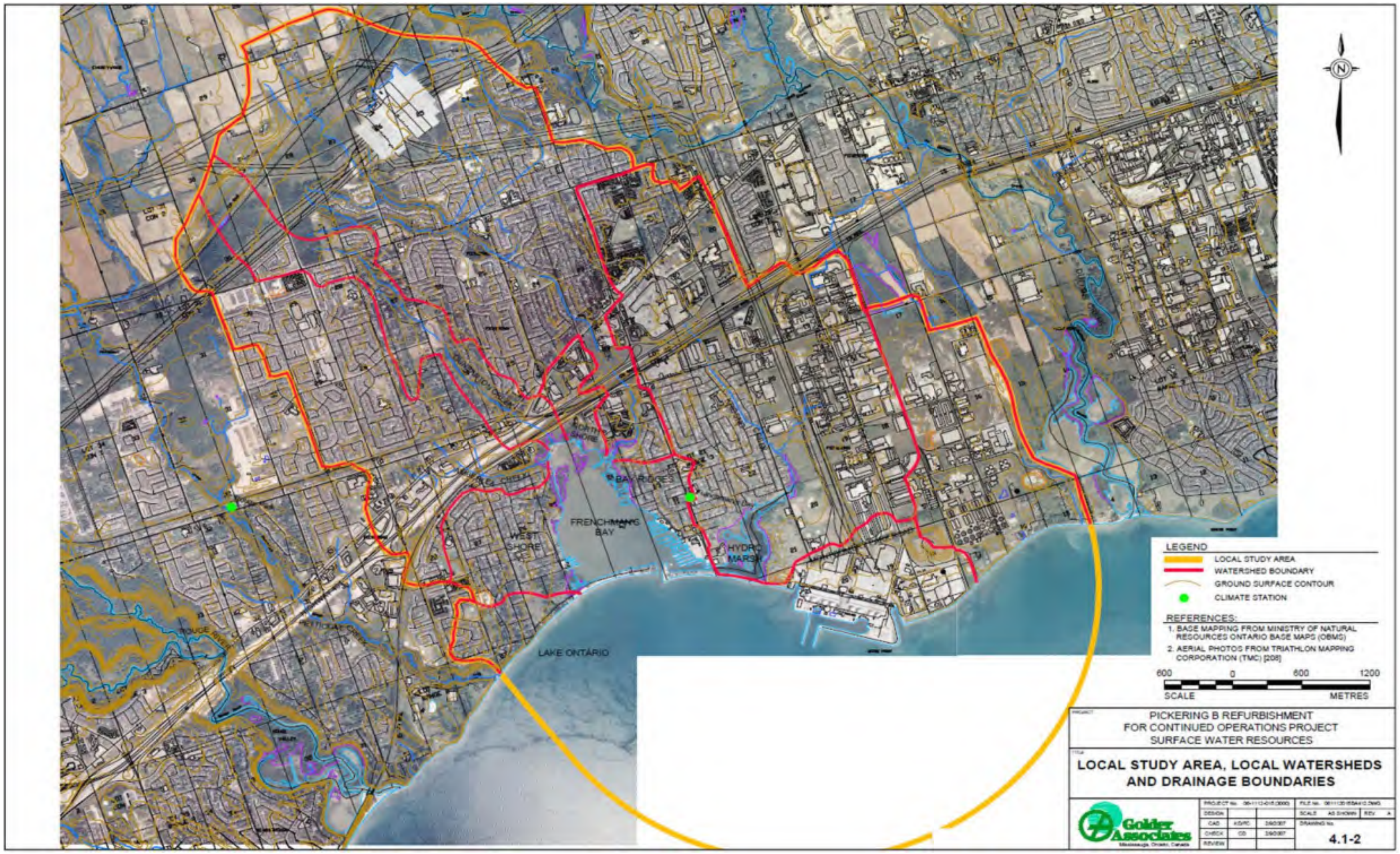
Lake Ontario is the farthest downstream of the five Great Lakes. It is the smallest in surface area but is substantially larger in volume, 1,640 km^3, than Lake Erie, which is located immediately upstream and empties into Lake Ontario via the Niagara River. The land area draining directly to

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.

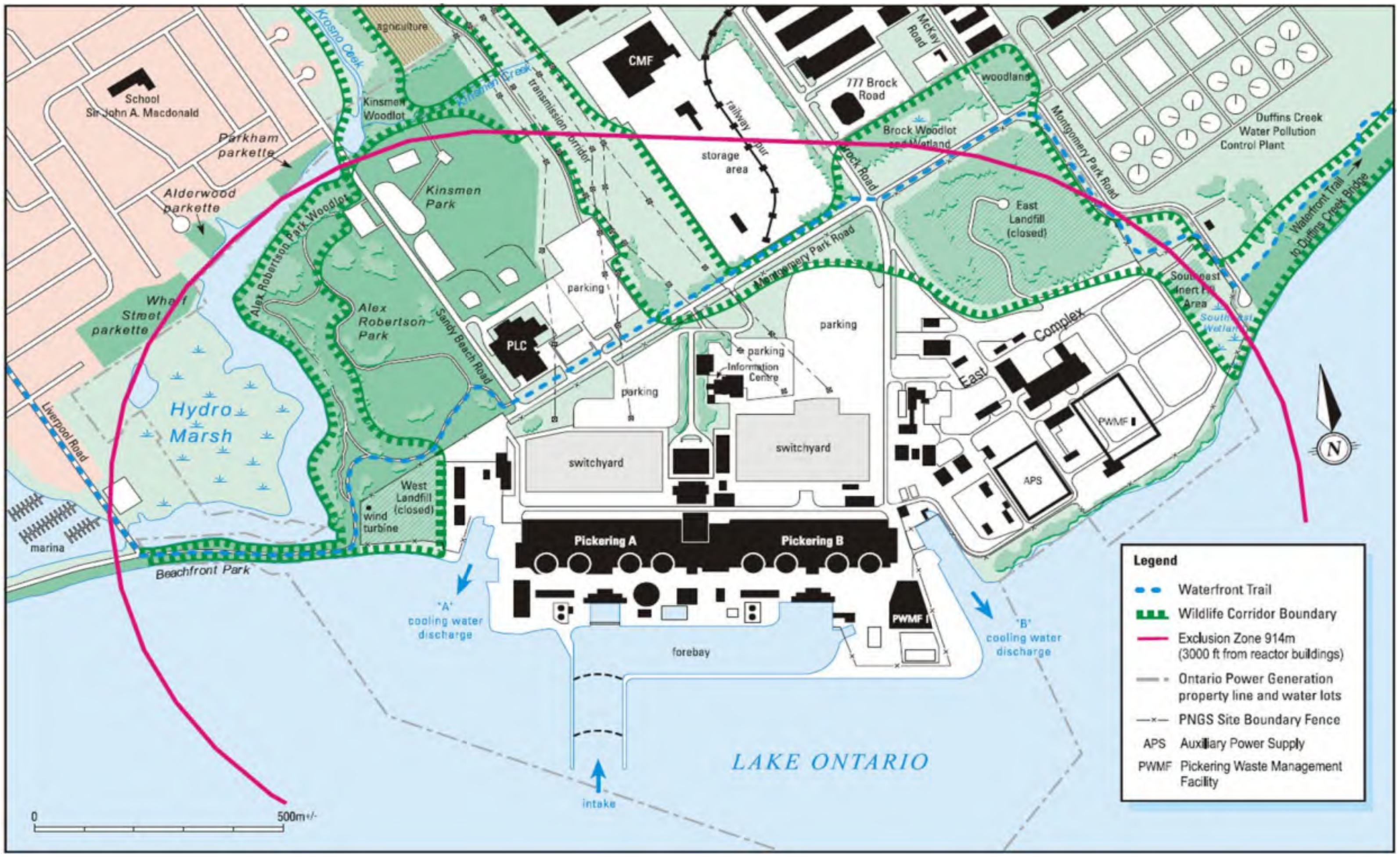
The PN site is surrounded by two major watersheds: the Rouge River watershed to the west and the Duffins Creek watershed to the east, as shown in Figure 2.15. Two smaller watersheds are located between the Rouge River watershed and the PN site. These are the Petticoat Creek watershed and the watershed 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

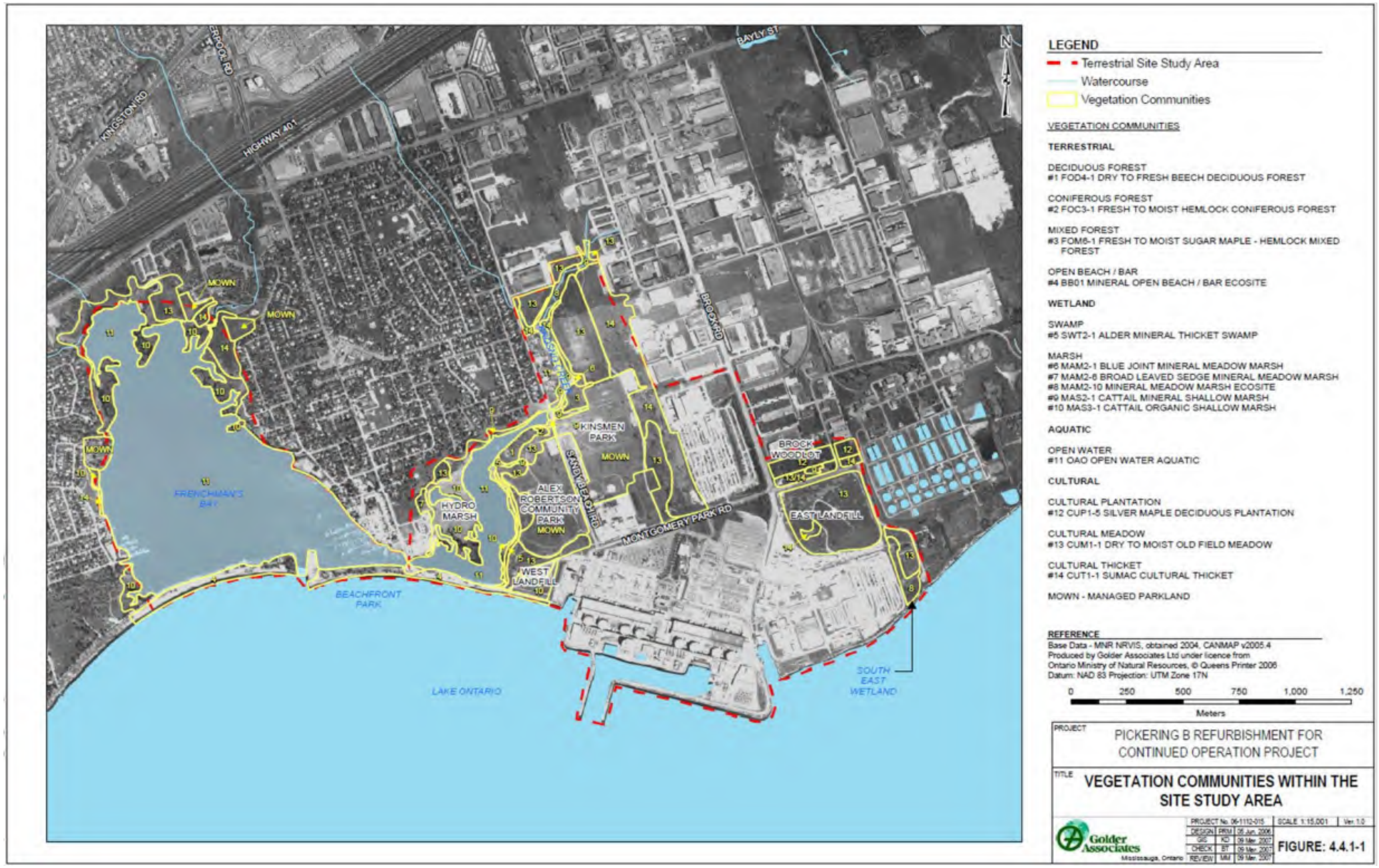
This section provides a brief overview of regional vegetation communities and summarizes existing vegetation communities located in the terrestrial SSA, as shown on Figure 2.17: Vegetation Communities Within and in the Vicinity of the PN Site. The site, local and regional vegetation communities and other 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

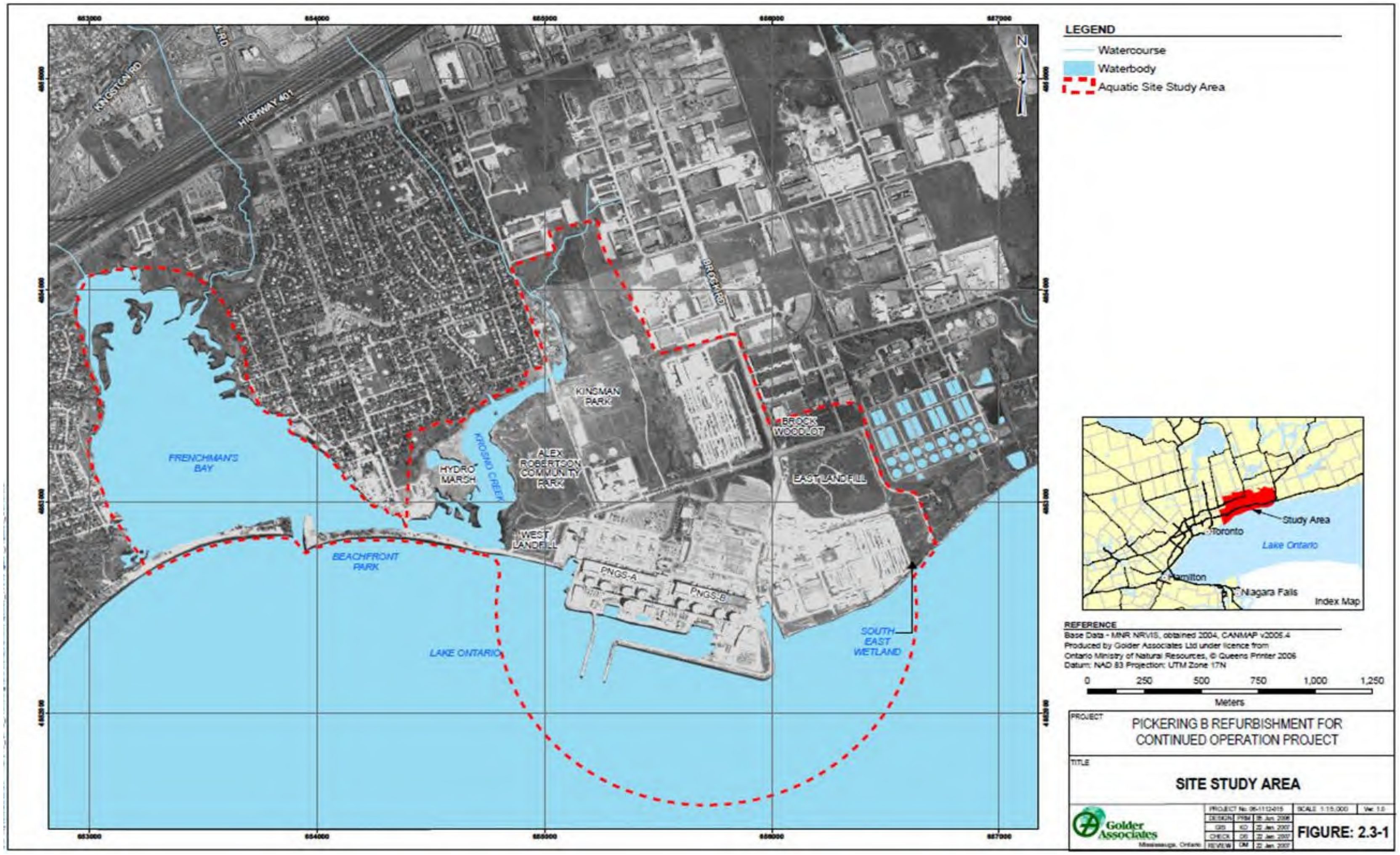
Notes:
The Provincial Species at Risk in Ontario List, Federal List of Wildlife Species at Risk (Schedule 1 of the Species at Risk Act (SARA)), and COSEWIC list are frequently revised.
Sources: (Beacon, 2017a, 2017b, 2018, 2019, 2020b; OPG, 2016b)

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.

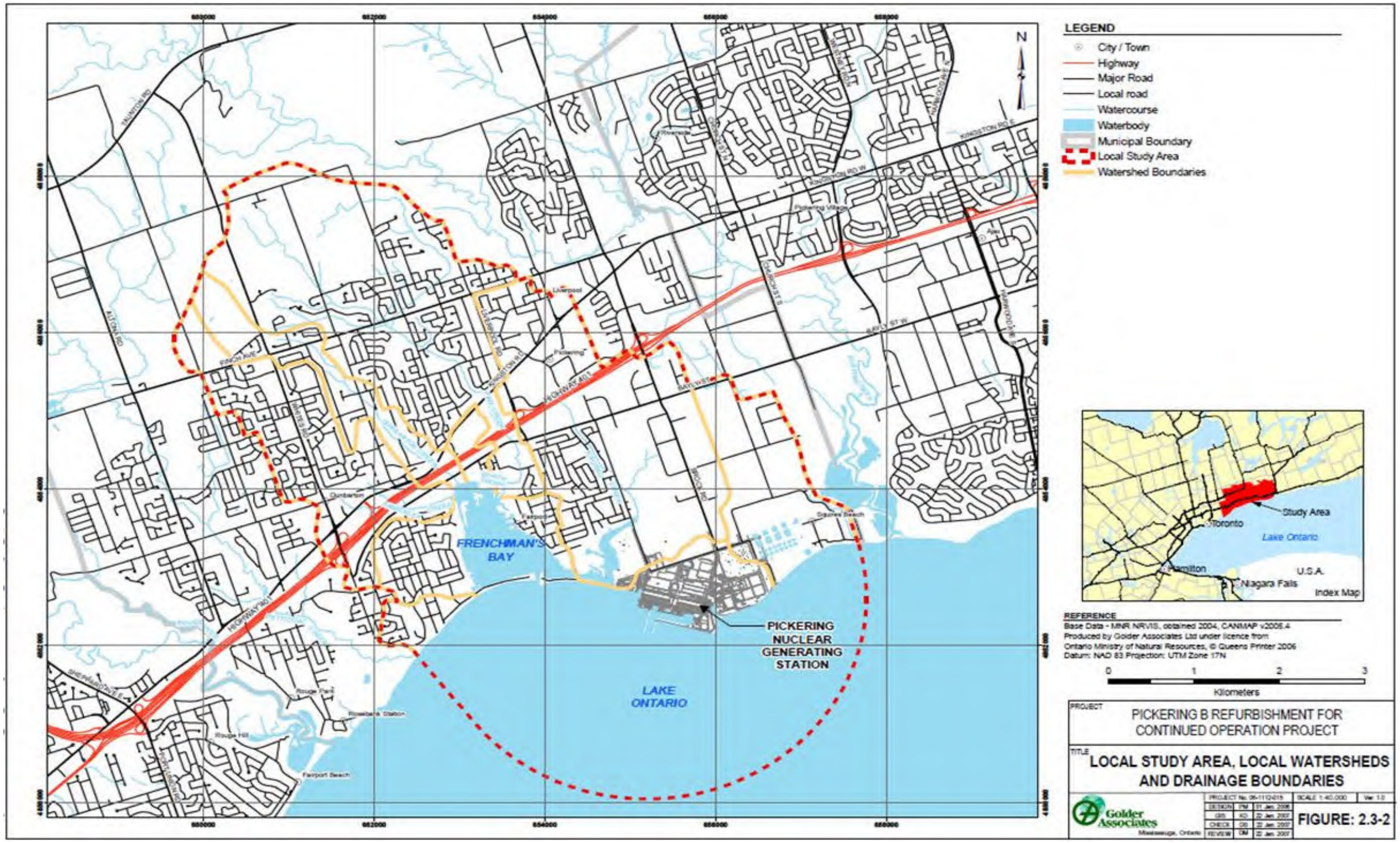
2.3.6 Aquatic Communities

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 $\mu g/m^3$.

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).

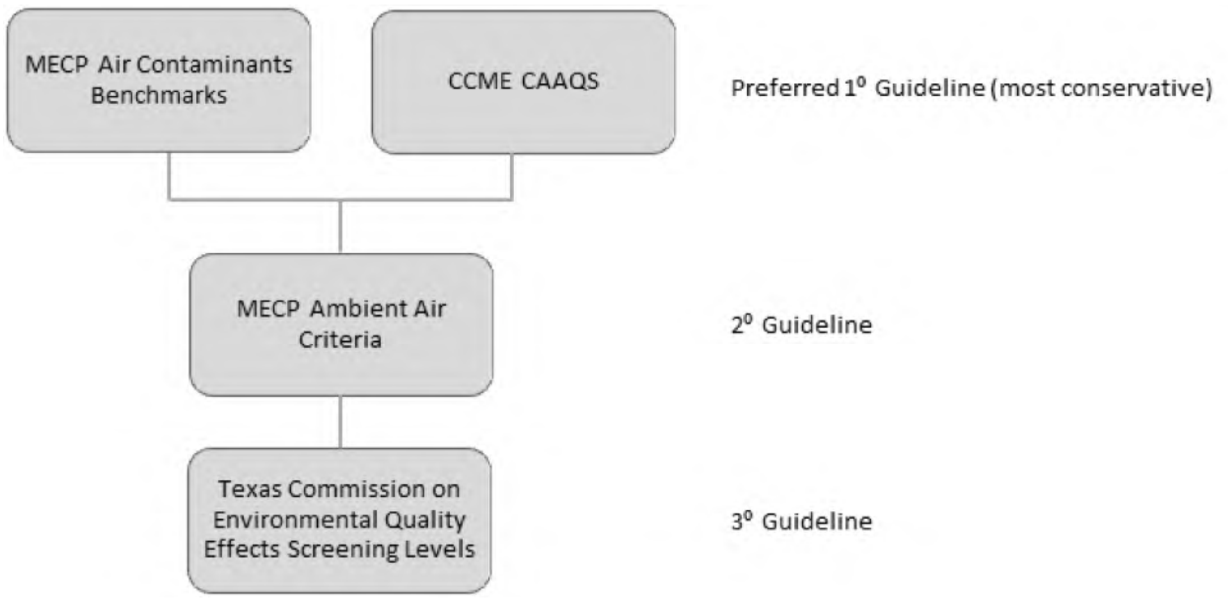


Figure 3.1: Screening Hierarchy for Chemical COPCs in Air for the HHRA

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 µg/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 µg/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 µg/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 µg/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:

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

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:

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

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.

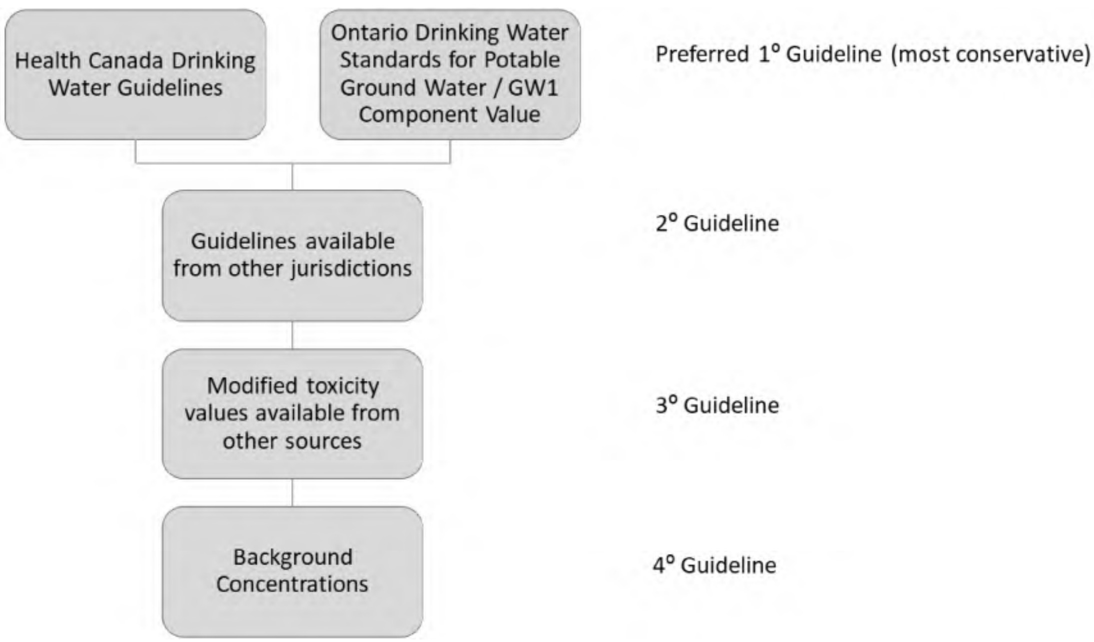


Figure 3.2: Screening Hierarchy for Chemical COPCs in Surface Water for the HHRA

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

<u>Notes:</u>
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.

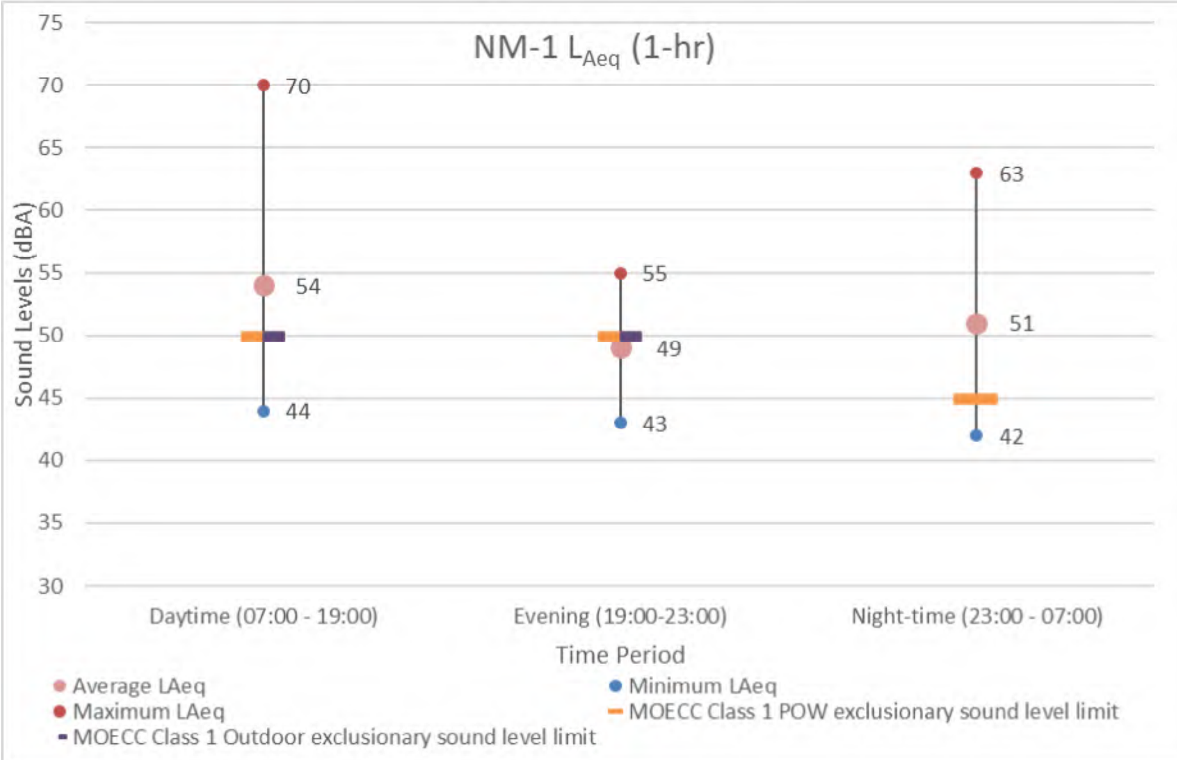


Figure 3.7: NM-1 Long-term Unattended Noise Monitoring L_{Aeq} (1-h) Overall Results

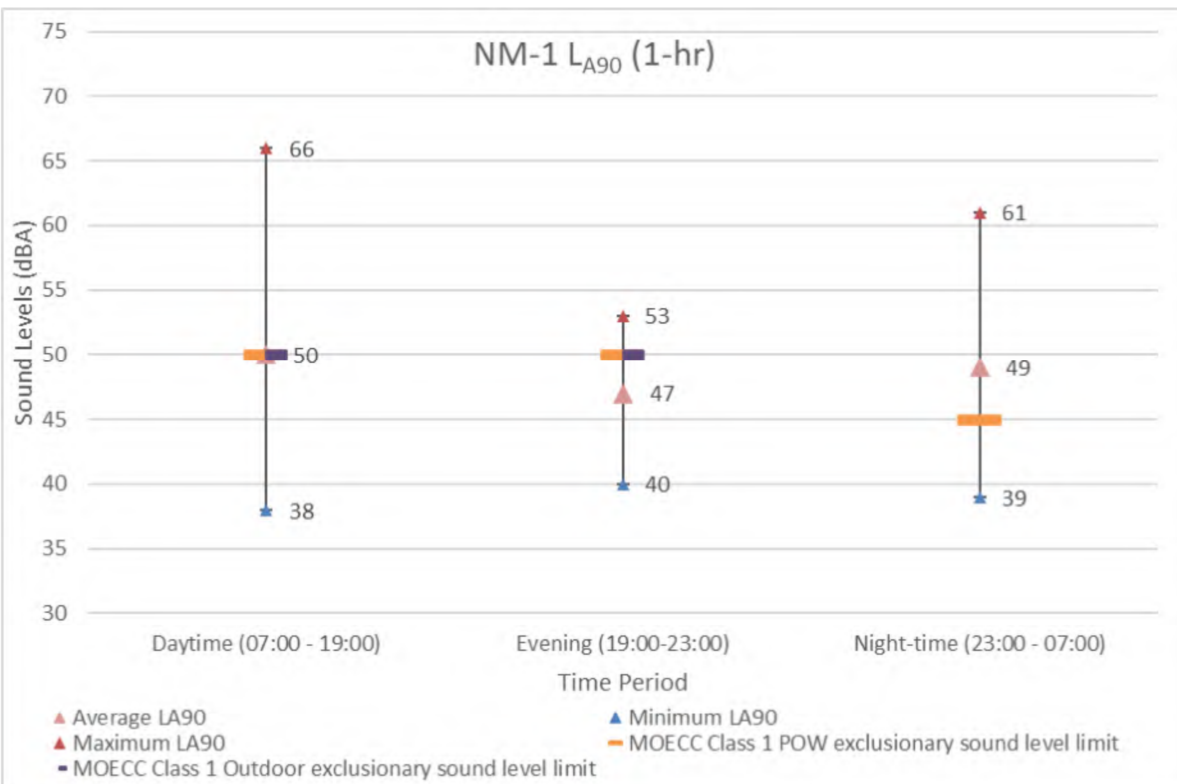


Figure 3.8: NM-1 Long-term Unattended Noise Monitoring L_{A90} (1-h) Overall Results

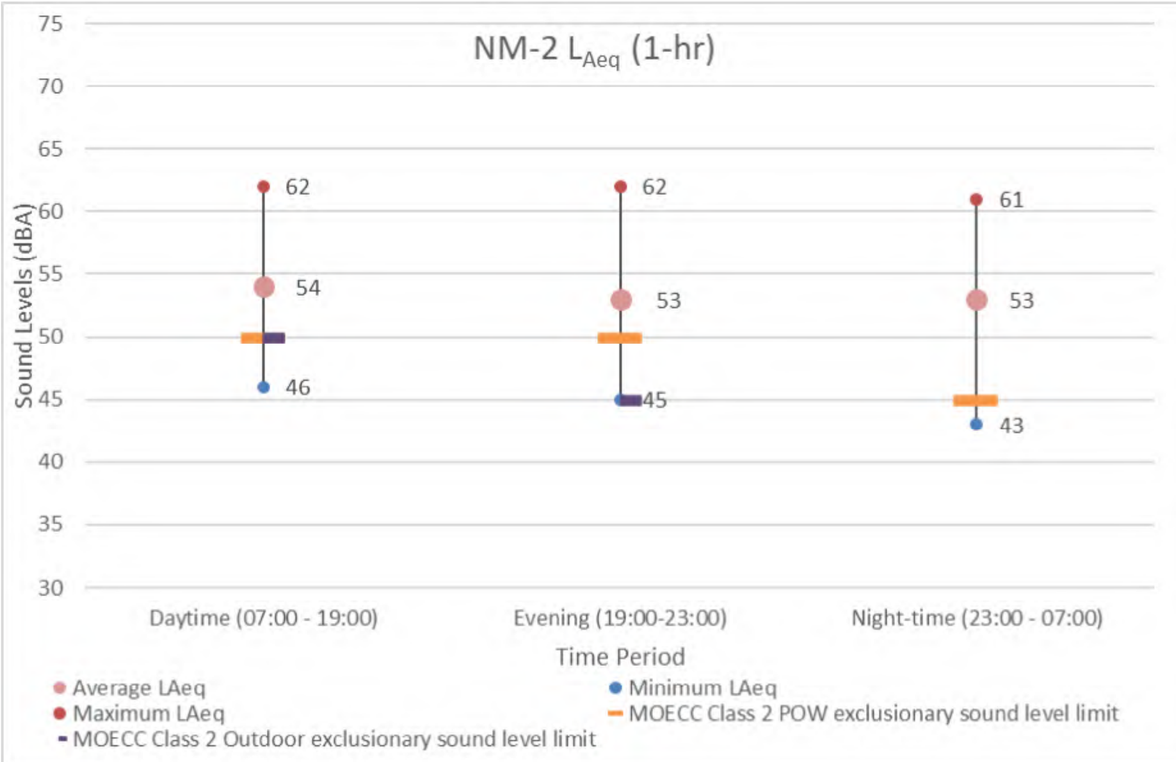


Figure 3.9: NM-2 Long-term Unattended Noise Monitoring L_{Aeq} (1-h) Overall Results

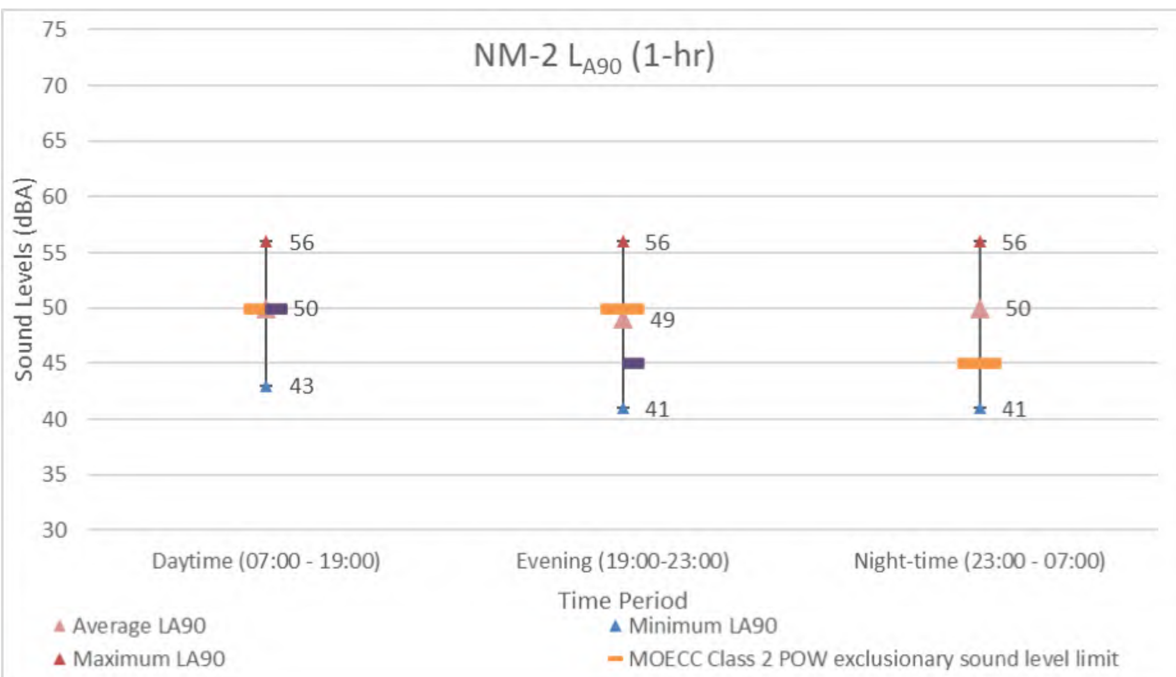


Figure 3.10: NM-2 Long-term Unattended Noise Monitoring L_{A90} (1-h) Overall Results

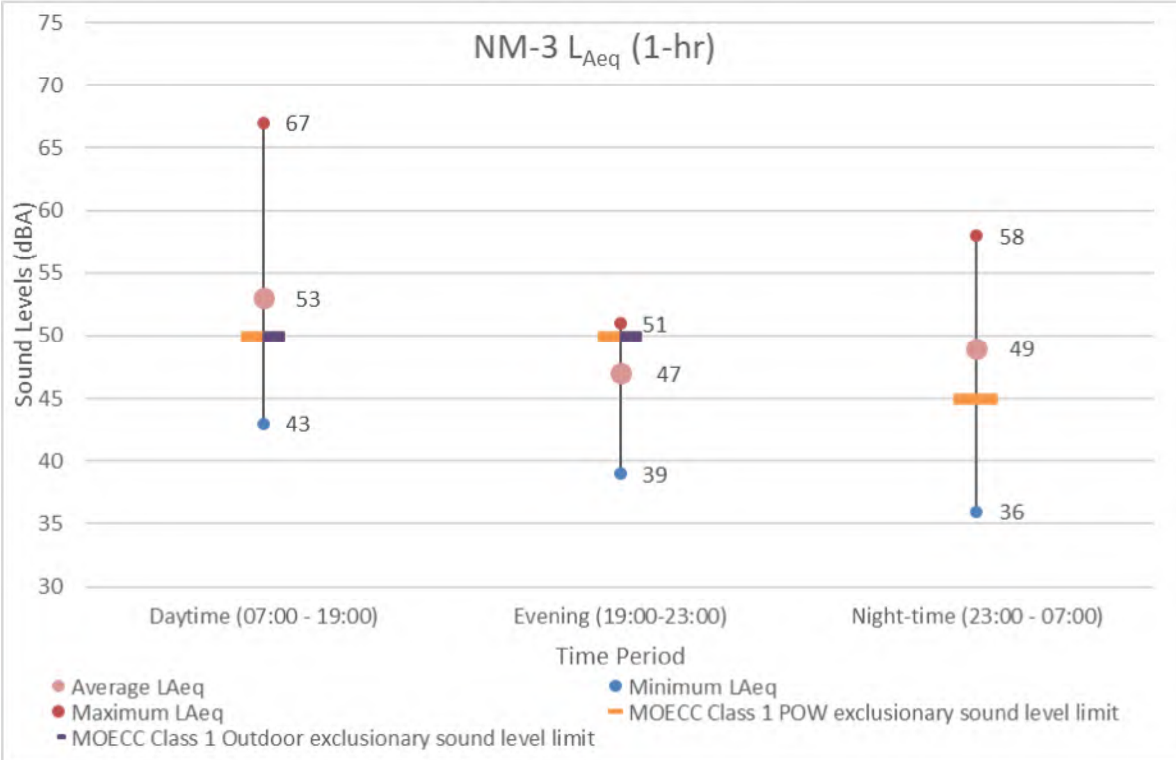


Figure 3.11: NM-3 Long-term Unattended Noise Monitoring L_{Aeq} (1-hr) Overall Results

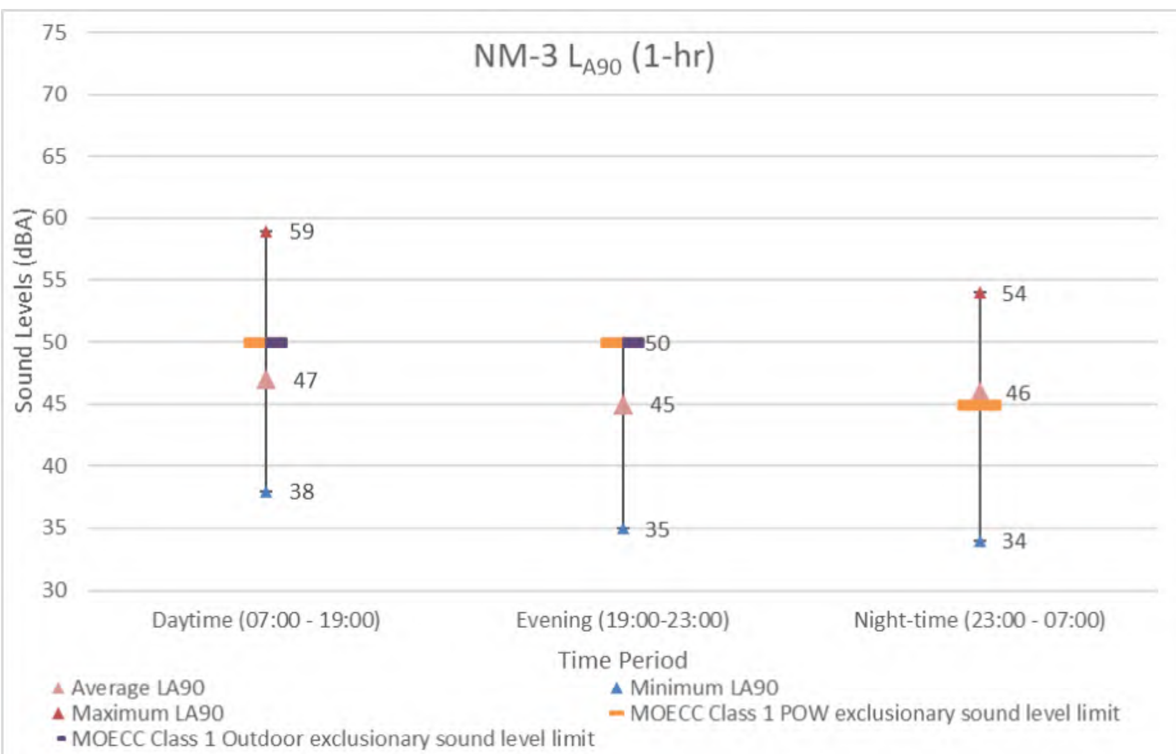


Figure 3.12: NM-3 Long-term Unattended Noise Monitoring L_{A90} (1-h) Overall Results

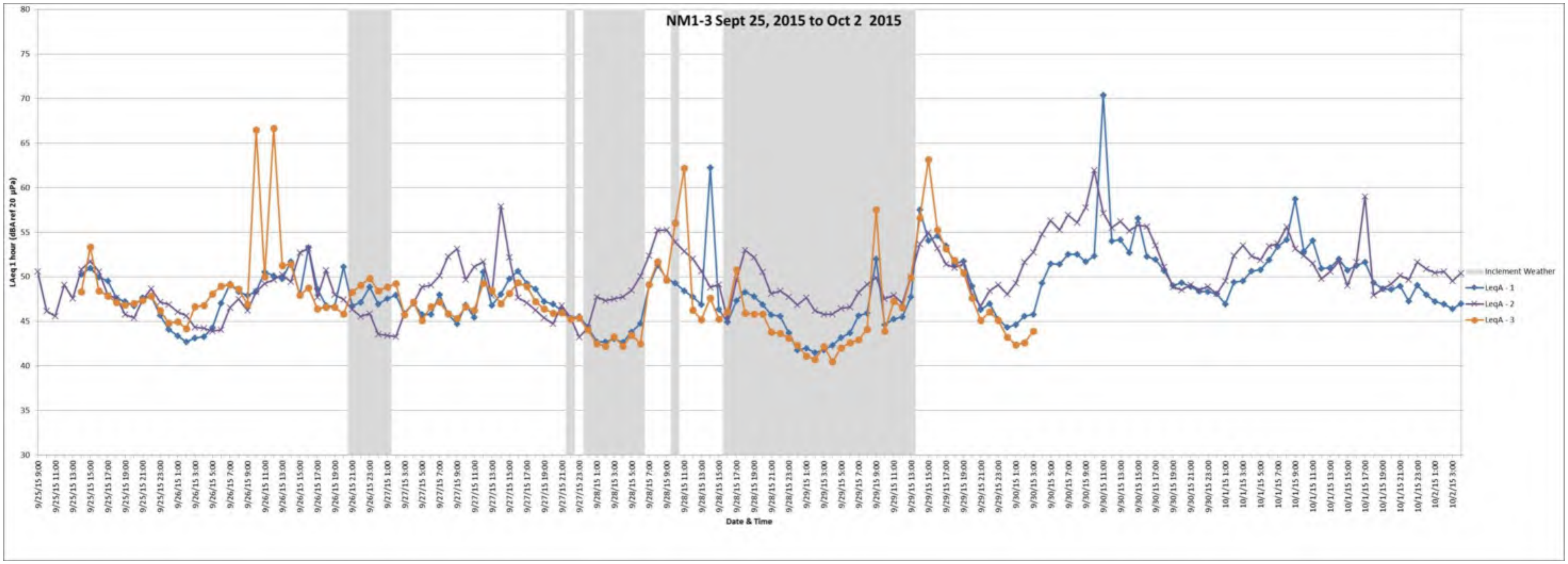


Figure 3.13: Environmental Noise Dataset (L_{Aeq} (1 h))

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

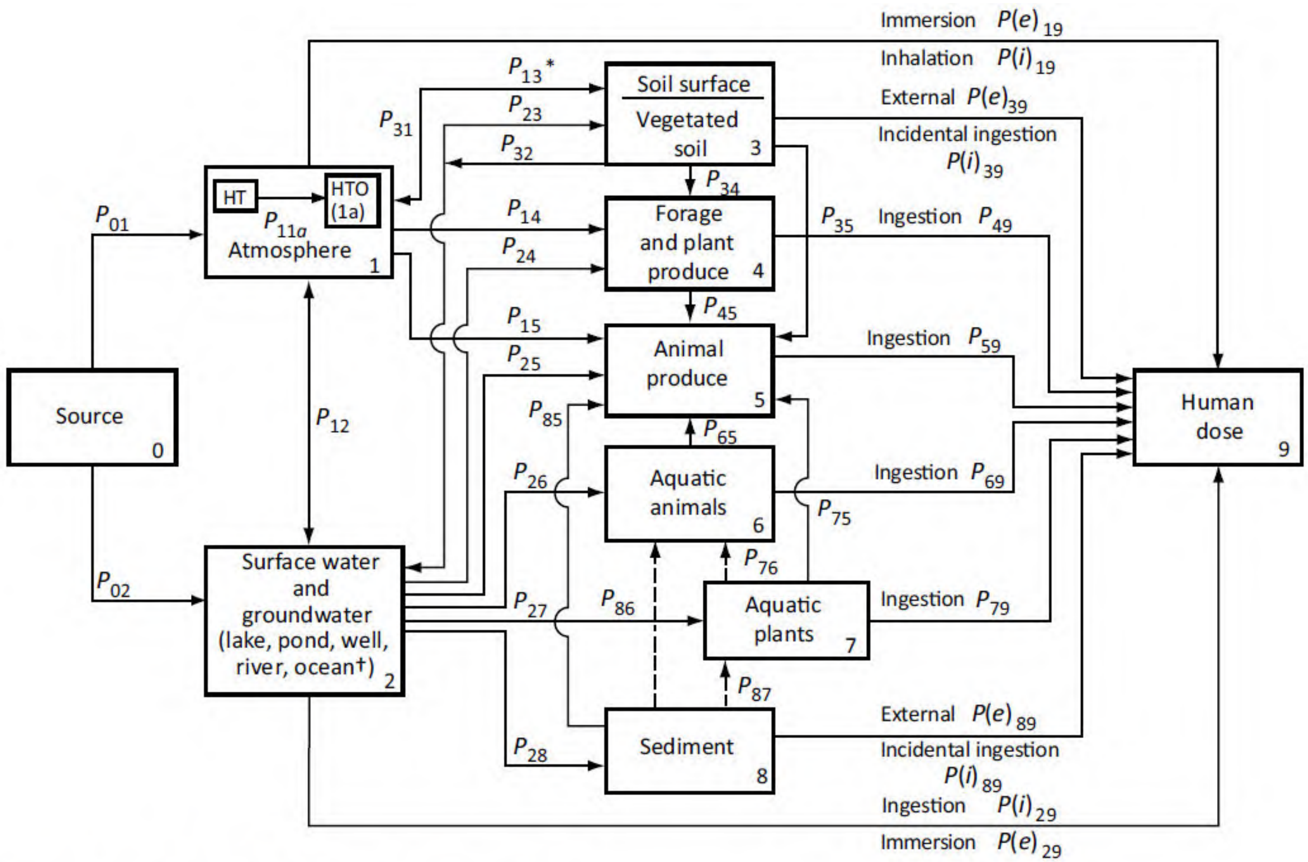
Receptor	Exposure Pathway	Environmental Media
Dairy Farm	Inhalation	Air
	Ingestion	Water (Wells) Soil (incidental) Sediment (incidental) Terrestrial plants (locally grown) Terrestrial animals (locally grown)
	External	Air Water Soil Sediment

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.

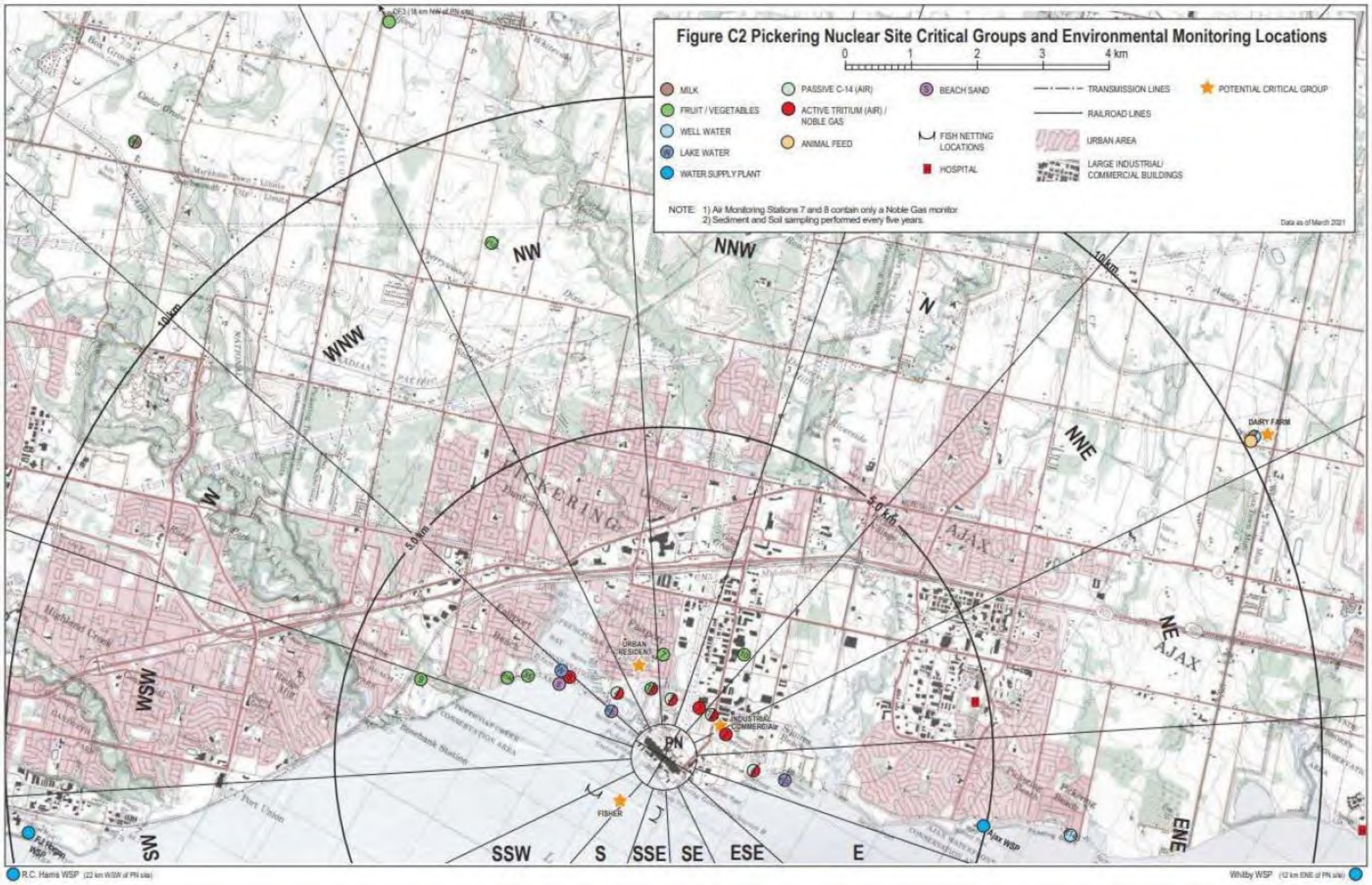
3.2.1 Exposure Locations

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) Aquatic animal intake rate(2) Terrestrial animal intake rates Terrestrial plant intake rates	L/a kg/a kg/a kg/a	0 1.68 262.3 144.5	151.1 4.82 286.3 331.1	379.6 6.86 255.5 440
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)

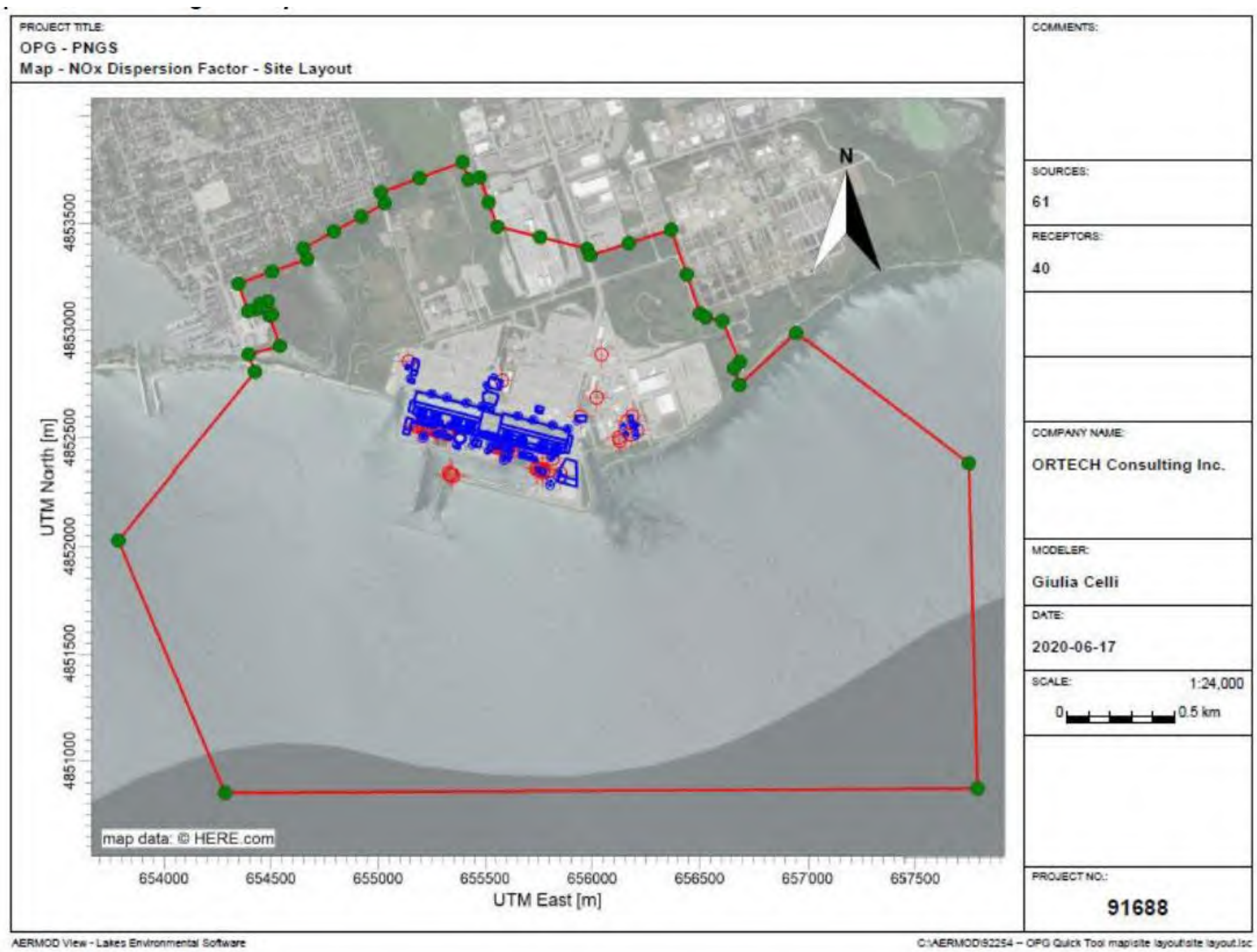


Figure 3.17: Receptor Locations Considered Along the Property Boundary and Lake Ontario

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 $\log K_{ow} < 1$.
(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 µg/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 µg/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 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)
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				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**	
	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.

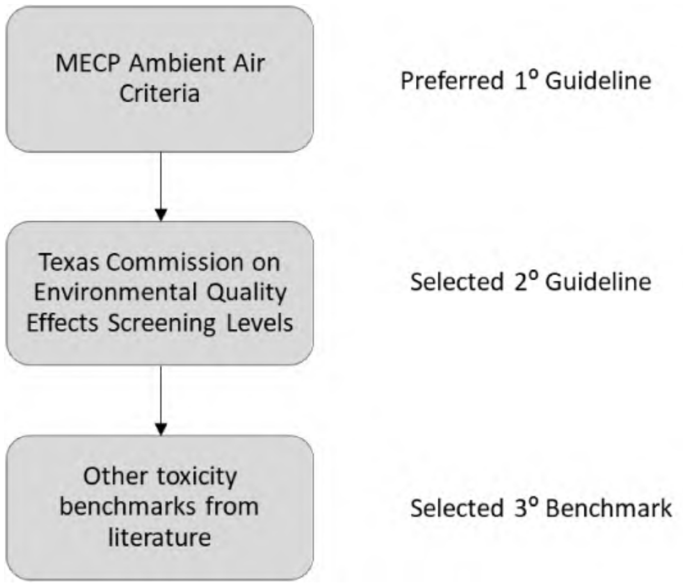


Figure 4.2: Screening Hierarchy for Chemical COPCs in Air for the EcoRA

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

Surface Water Screening

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.

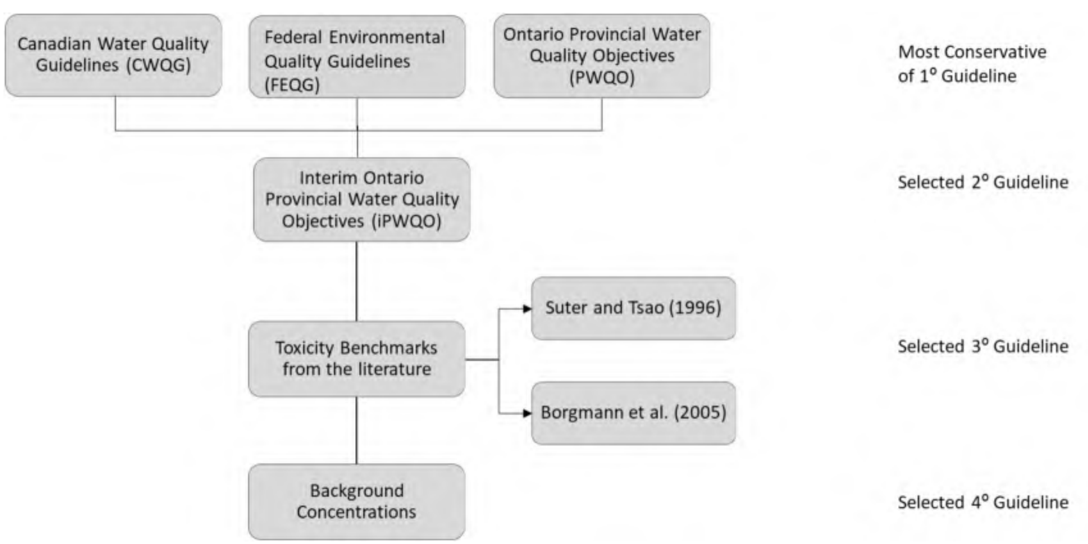


Figure 4.3: Selection of Screening Criteria for Chemical COPCs in Surface Water

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%.

Sediment Screening

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.

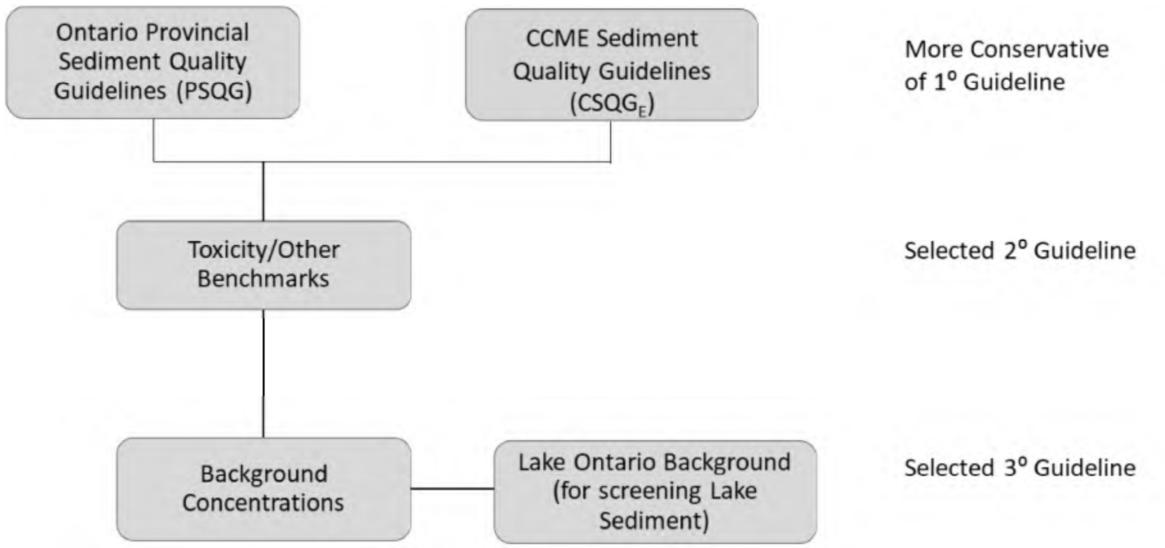


Figure 4.4: Screening Criteria for COPCs in Sediment

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.

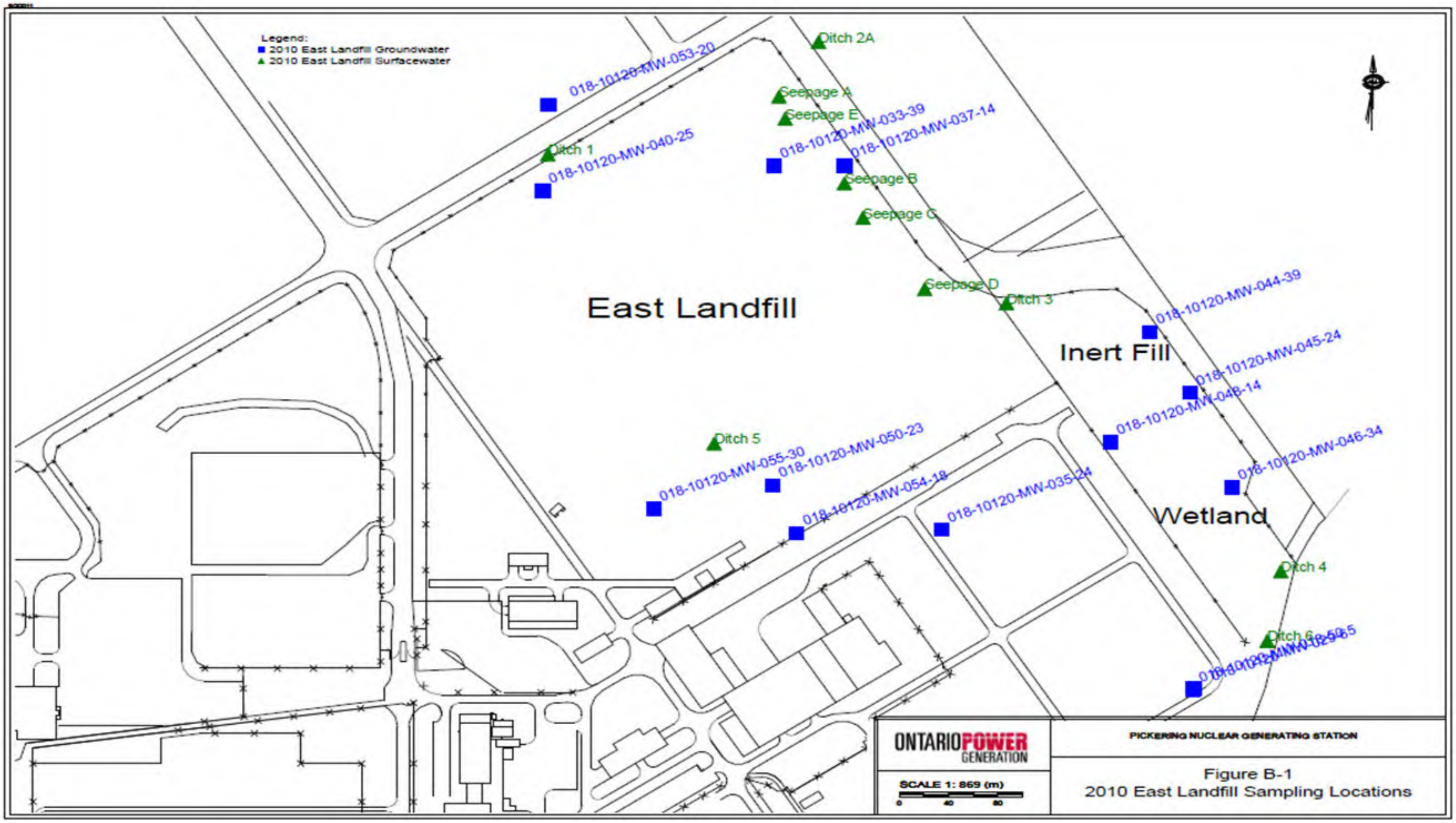
Assessment of Sulphate in the 2017 ERA

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.

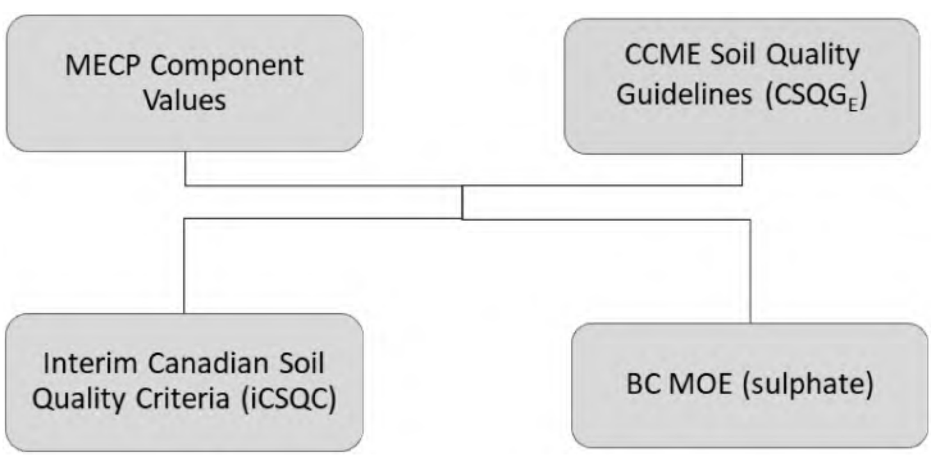


Figure 4.8: Selection of Screening Criteria for Chemical COPCs in Soil

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).

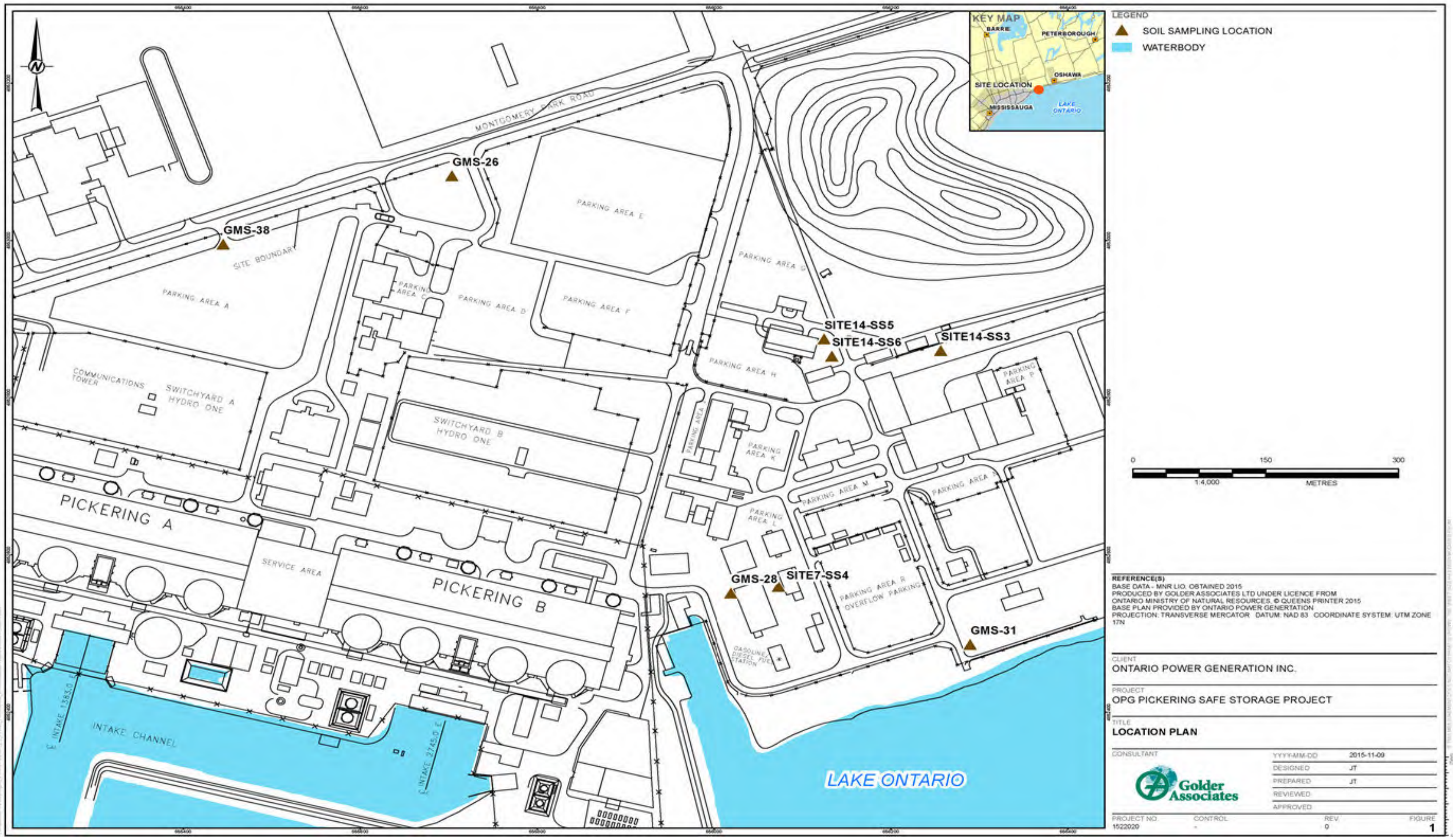


Figure 4.9: 2015 Soil Sampling Locations

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).

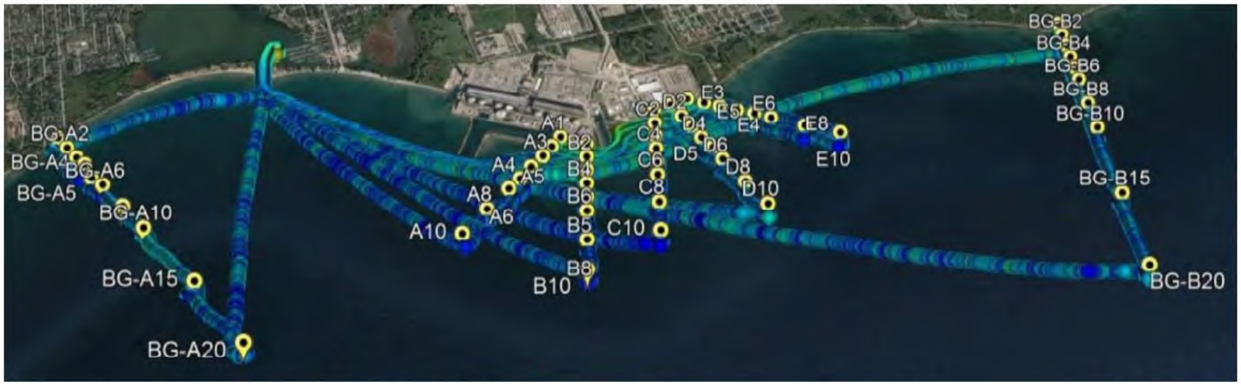
Ar-41 emissions are evaluated for human receptors through the annual EMP reports and is carried forward as a COPC for the EcoRA. The dose to non-human biota from exposure to noble gases (predominantly Ar-41) is presented in the Exposure Assessment.

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.

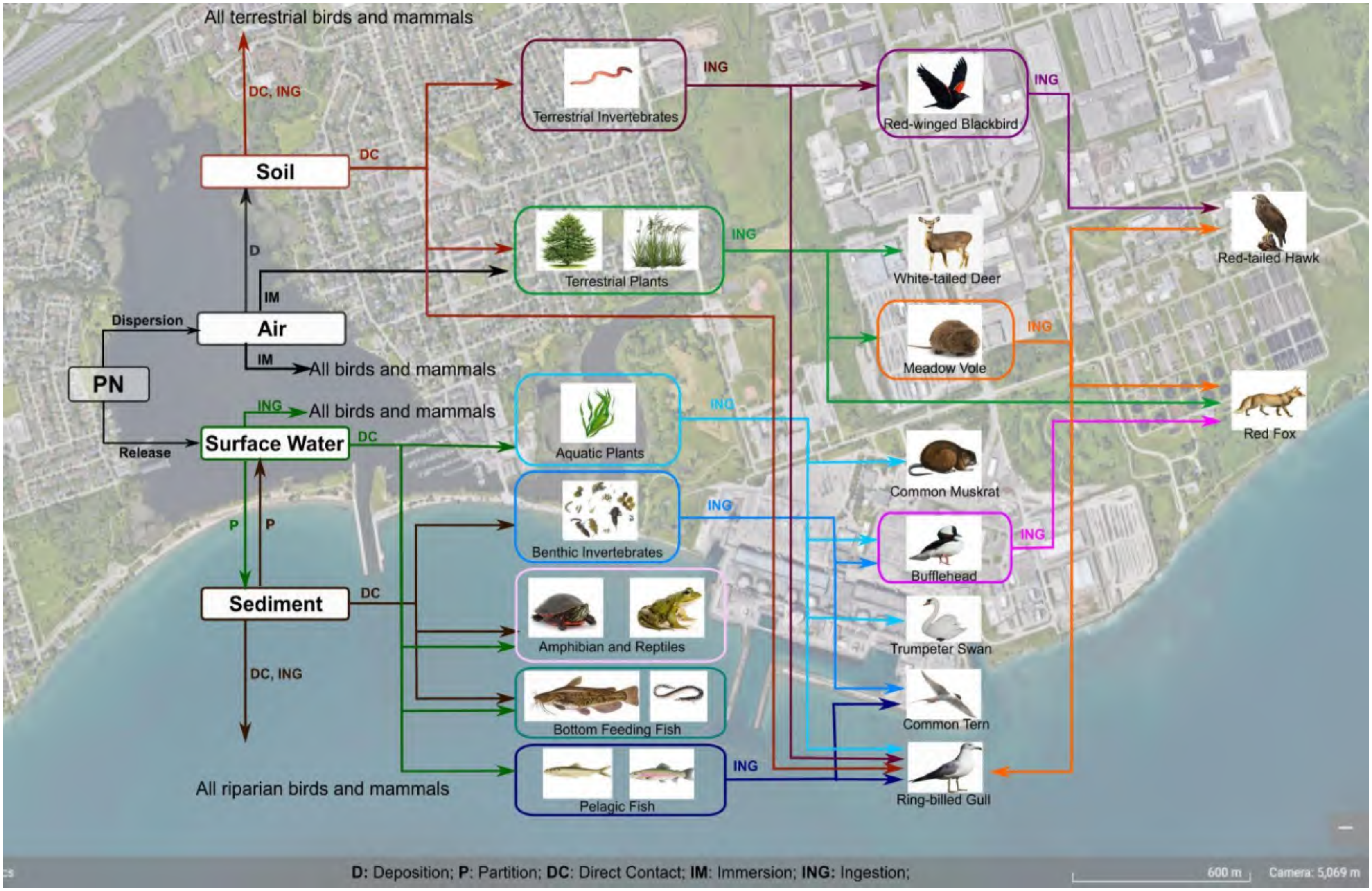


Figure 4.12: Conceptual Model for the Ecological Risk Assessment

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

<u>Note:</u>
*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.

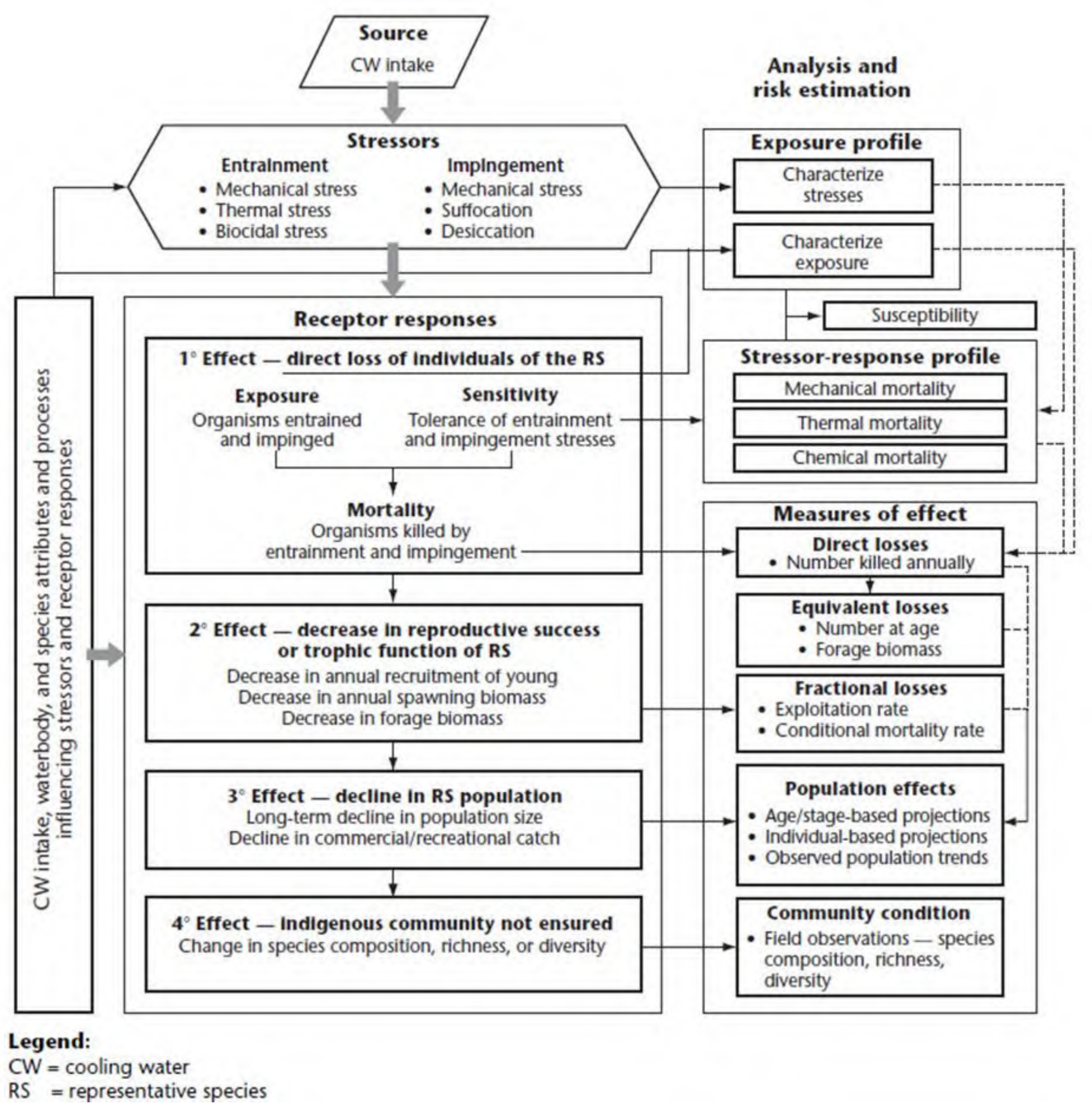


Figure 4.13: Conceptual Model for Relationships between Individual Endpoints and Population/Community Endpoints (CSA, 2012)

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	m³/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/m³)	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/m³)	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):

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

where,

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

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:

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

where,

k_{af} = fraction of food from contaminated sources
$f_{w\text{-}pw}$ = fraction of the animal water intake derived from water in 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)
$\Delta\theta$ = 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.

6.0 References

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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)						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	
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: Mean Background in 2015 (LWC-1)	2015 Lake Water Results: Maximum Observed Lake Water in 2015	Screening Criteria: Selected Screening Level	Screening Criteria: Source / Basis	Carried Forward as COPC for the HHRA?
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

		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						
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	Units	Concentration								Units	Loading								Max Loading	Units	Screening			Mean Background in 2015 (LWC-1)	Carried Forward as COPC for the HHRA?
		Catchment 10				Catchment 13					Catchment 10				Catchment 13						Final Concentration in Lake	Screening Criteria			
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							
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

		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)	Carried Forward as COPC for the HHRA?
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	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							Screening					
		Catchment 3							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)							
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

Location	Units	Concentration Catchment 3 MH211						Unit	Loading Catchment 3 MH211						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?
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

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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

		Catchment 8					Catchment 6				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	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	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					Catchment 6				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	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							
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

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.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								
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

Location / Station ID / Date	Concentration Units	Concentration Catchment 10 M2-1 20-Aug-15	Concentration Catchment 10 M2-1 28-Oct-15	Concentration Catchment 10 M2-1 19-Nov-15	Concentration Catchment 10 M2-1 11-Jun-16	Concentration Catchment 13 M5-1 20-Aug-15	Concentration Catchment 13 M5-1 28-Oct-15	Concentration Catchment 13 M5-1 19-Nov-15	Concentration Catchment 13 M5-1 11-Jun-16	Loading Units	Loading Catchment 10 M2-1 20-Aug-15	Loading Catchment 10 M2-1 28-Oct-15	Loading Catchment 10 M2-1 19-Nov-15	Loading Catchment 10 M2-1 11-Jun-16	Loading Catchment 13 M5-1 20-Aug-15	Loading Catchment 13 M5-1 28-Oct-15	Loading Catchment 13 M5-1 19-Nov-15	Loading Catchment 13 M5-1 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)	Exceeds Screening Criteria?	Carried Forward as COPC for the EcoRA?
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

Location	Units	Concentration						Unit	Loading						Max Loading	Screening						
		Catchment 3							Catchment 3							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		Exceeds Screening Criteria?	Carried Forward as COPC for the EcoRA?	Notes
				Selected Screening Level	Source / Basis			
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		Exceeds Screening Criteria?	Carried Forward as COPC for the EcoRA?	Notes
				Selected Screening Level	Source / Basis			
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%

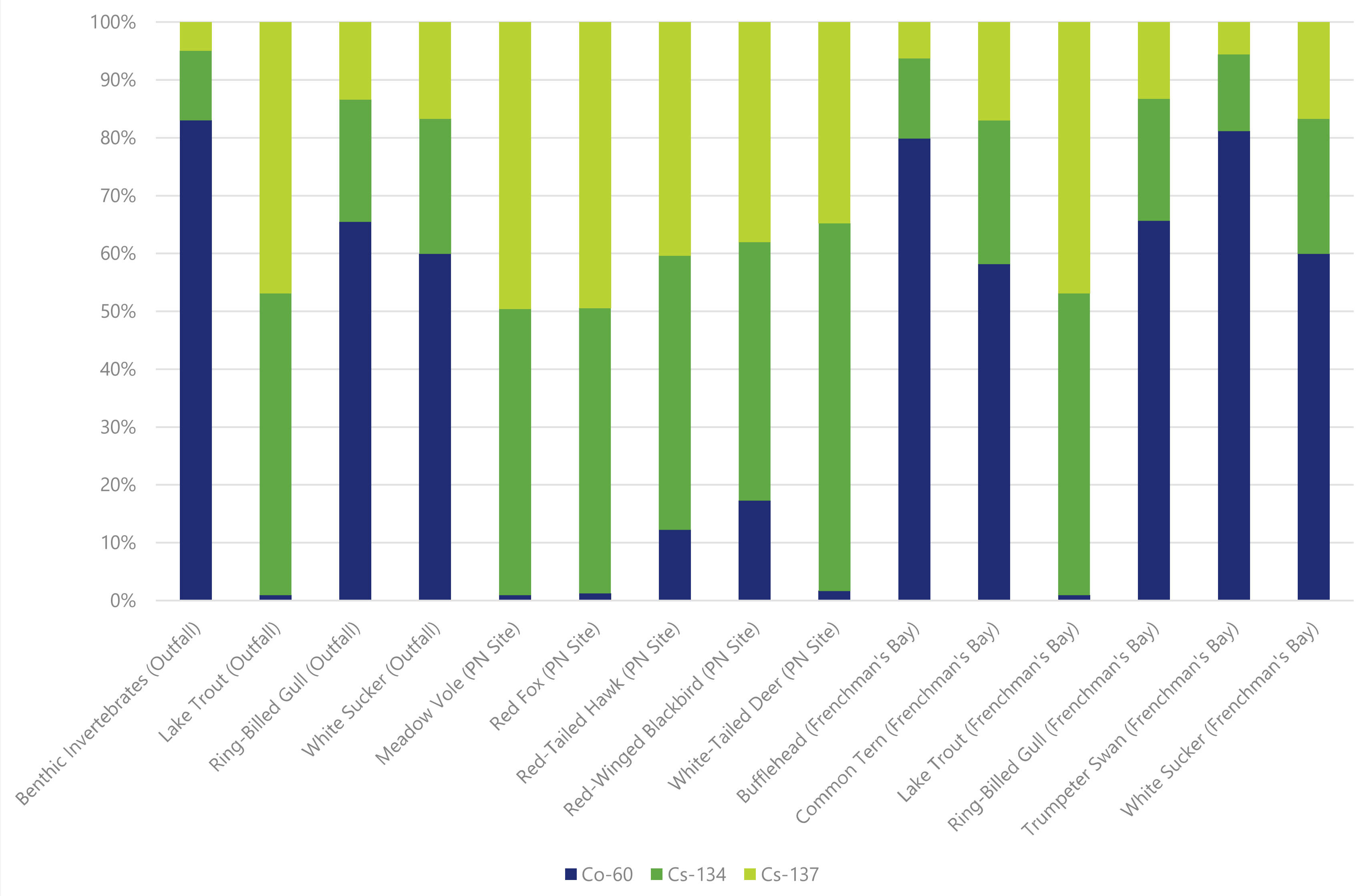

Figure C-1: Relative Contribution to Dose

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.

C.5 References

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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	$\lambda = \ln(2)/t½$	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	$C_{hydrazine\ (t½\ =1.3)}$	$C_{hydrazine\ (t½\ =1.3)} = C_w * EXP(-\lambda t)$	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}'	$D_{int}' = D_{int} * 24\ h/d / 1000\ \mu Gy/mGy$	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}'	$D_{ext}' = D_{ext} * 24\ h/d / 1000\ \mu Gy/mGy$	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/m³	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/m²	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/m²)	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

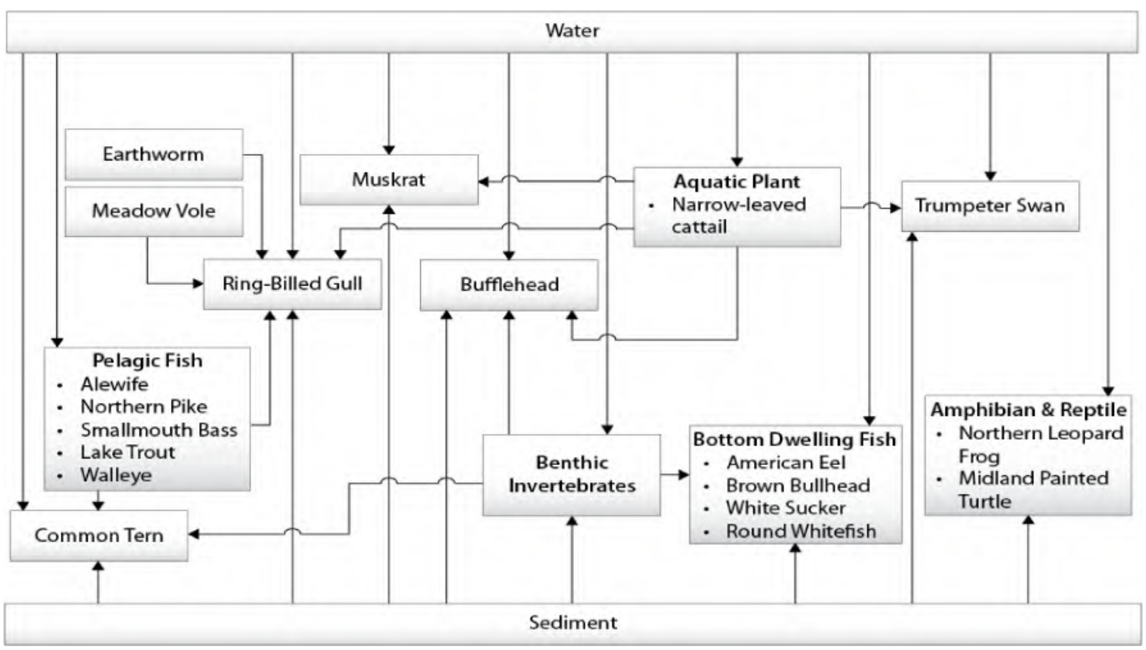
Water COPC	Sediment COPC
Total Aluminum Copper** Iron Sodium	Aluminum** Bismuth* Boron* Cadmium Calcium* Chromium Copper Iron Lead Manganese Nickel Phosphorus Thallium* Tin* Zinc

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

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

P-REP-07701-00006 R001

REPORT PREPARED FOR:

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

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

LAND ACKNOWLEDGMENT

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

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

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

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

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

LIST OF ACRONYMS AND SYMBOLS

ACRONYMS

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

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

SYMBOLS

Environmental Partitioning Parameters

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

Ecological Radiological Dose Parameters

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

Ecological Tissue Concentration Parameters

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

Specific Activity Model for Tritium Parameters

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

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

Specific Activity Model for Carbon-14 Parameters

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

EXECUTIVE SUMMARY

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

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

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

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

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

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

Objectives and Methodology of the PEA Addendum Report

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

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

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

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

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

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

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

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

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

Results / Conclusions of the Updated Assessments

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

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

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

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

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

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

Recommendations

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

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1.0 Introduction

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

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

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

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

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

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

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

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

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

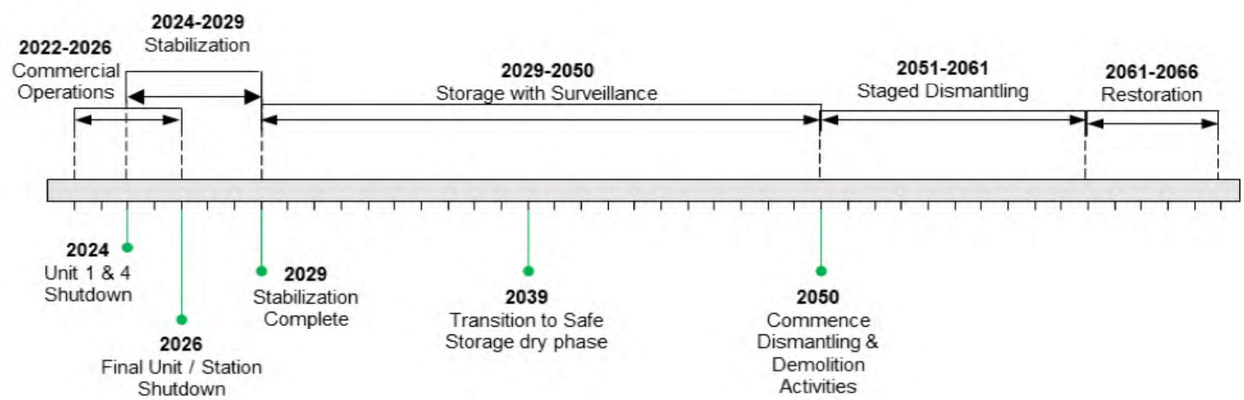


Figure 1.1: Conceptual Timeline for the Continued Operation and Shutdown Phases of PNGS

1.1 Project Overview

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

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

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

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

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

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

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

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

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

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

1.2 Regulatory Context

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

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

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

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

1.3 Summary of the 2017 Predictive Effects Assessment

1.3.1 Objectives and Scope of the 2017 PEA

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

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

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

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

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

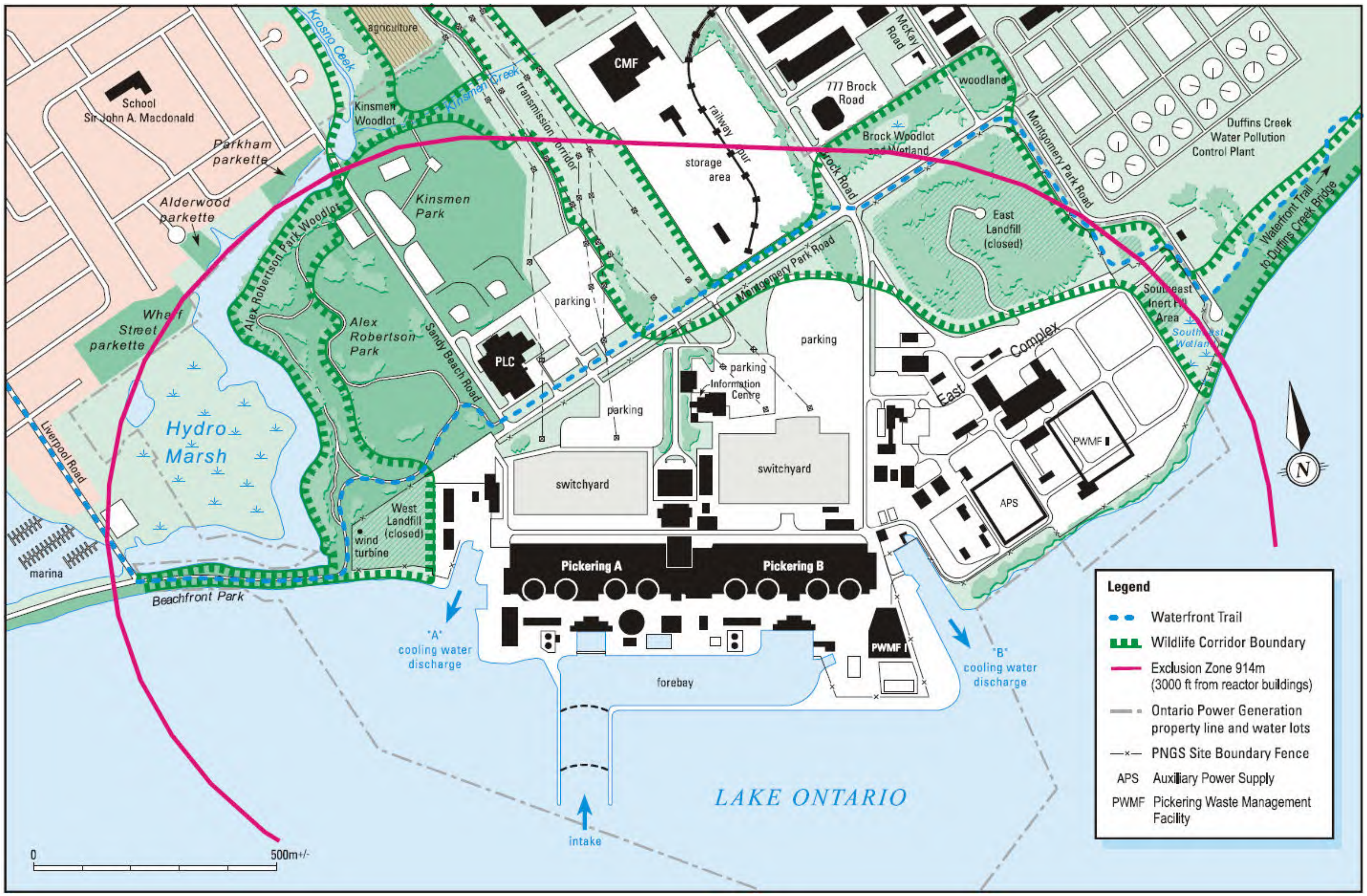


Figure 1.2: Conceptual Layout of PNGS (Golder and Ecometrix, 2017)

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

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

1.3.2 Methodology of 2017 PEA

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

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

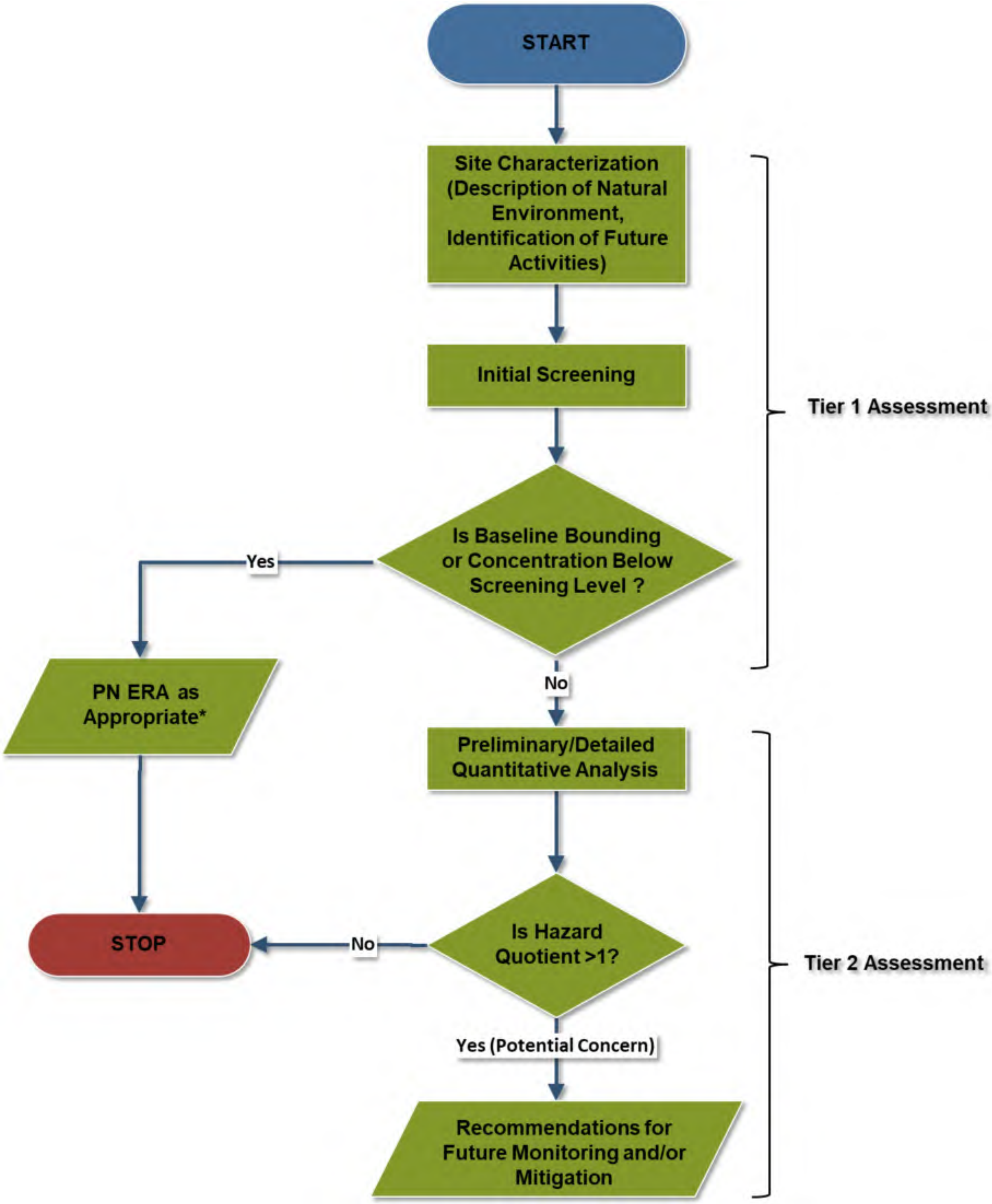
- An initial screening (Tier 1 Assessment); and
- A preliminary/detailed quantitative analysis (Tier 2 Assessment).

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

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

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

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



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

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

1.3.3 Results of 2017 Tier 1 Assessment

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

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

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

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

1.3.4 Results of 2017 Tier 2 Assessment

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

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

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

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

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

1.3.5 Conclusions and Recommendations of the 2017 PEA

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

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

1.4 Quality Assurance and Quality Control

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

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

2.0 Objectives and Scope of the PEA Addendum Report

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

Specifically, the PEA Addendum report will:

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

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

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

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

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

3.0 Methodology of the PEA Addendum Report

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

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

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

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

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

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

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

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

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

4.0 Update of Existing and Future Conditions

4.1 Baseline Conditions Update

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

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

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

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

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

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

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

4.1.1 Indigenous Engagement

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

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

4.2 Stabilization and Storage with Surveillance Phase Activities Update

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

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

4.2.1 Changes to Systems, Structures or Activities

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

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

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

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

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

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

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

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

4.2.2 Pickering Waste Management Facility

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

4.3 Updated Lake Data Review

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

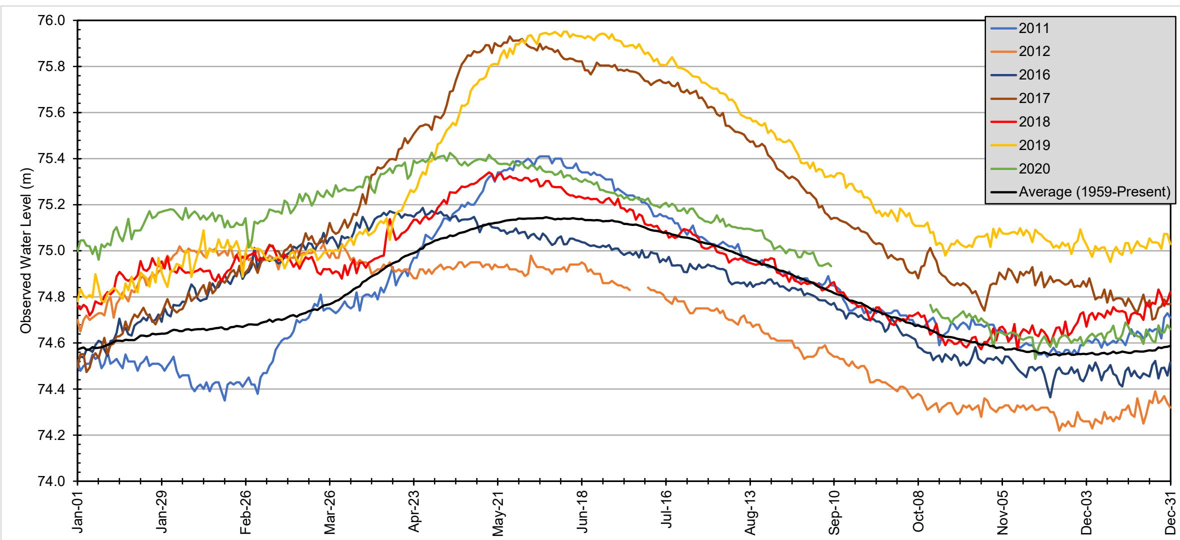
The key changes to the assumptions for surface water modelling are the potential increase in cooling water intake flow from 50,000 m^3/day assumed in the 2017 PEA to 250,500 m^3/day, and the re-routing of groundwater inputs from the TAB inactive drainage sumps and Vacuum Building Ramp Sump (VBRS) into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

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

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

4.3.1 Water Levels

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



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

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

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

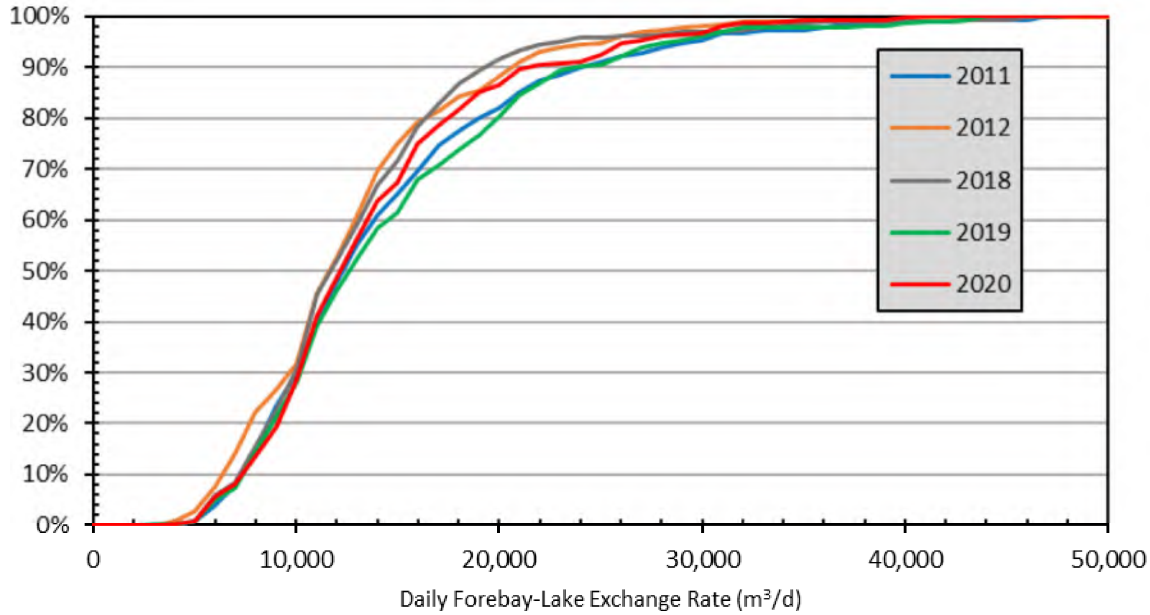


Figure 4.2: Frequency of Estimated Daily Water Level Driven Forebay Exchange Rates Using the Forebay Model

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

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

4.3.2 Water Temperature

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

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

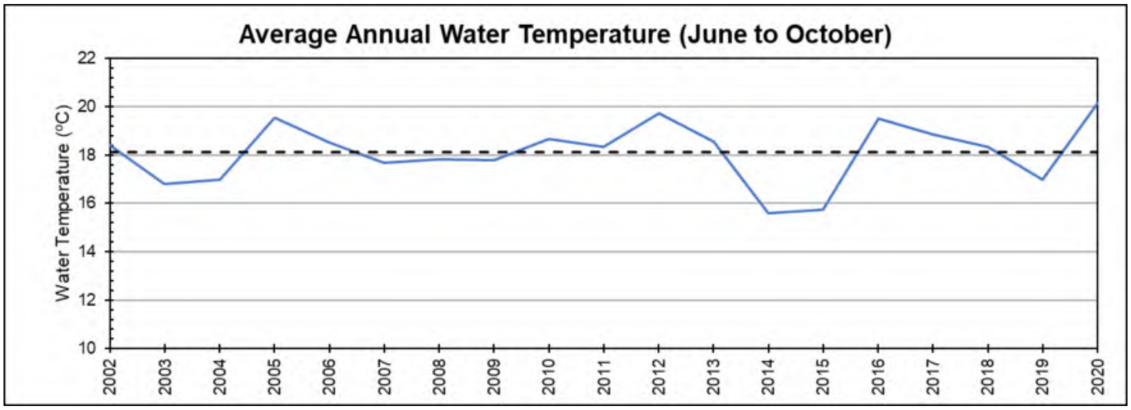


Figure 4.3: Annual Average Water Temperature at Buoy 45012

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

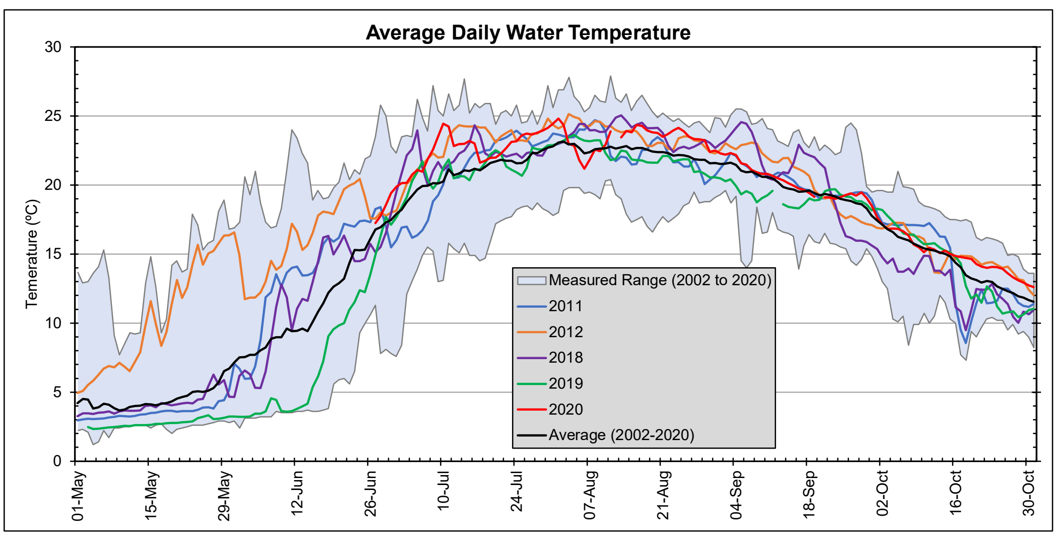


Figure 4.4: Average Daily Water Temperature (Buoy 45012)

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

4.3.3 Water Currents

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

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

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

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

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

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

Notes for Table 4.2 and Table 4.3:

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

4.4 Climate Change Considerations

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

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

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

- Water temperature (annual average) is expected to increase in Lake Ontario by 0.7°C by mid-century (Ouranos, 2017). With respect to the time period of the PN PEA, water temperatures are predicted to increase between 0.26°C and 2.9°C by 2039. As the site discharges from PNGS during the Storage with Surveillance Phase are non-thermal and small in volume, changes to the behaviour of the plumes associated with PNGS as a result of increase to water temperature are not expected between now and 2039.
- Water levels will likely increase. Older references predicted water levels would drop at a rate of approximately 0.005 m/year, which would lower the water level by approximately 0.09 m by 2039 (Gronewold et al., 2013). More recent methods suggest modest drops and indicate older methods over-estimated evapotranspiration (ELPC, 2019). Lake level modelling using a net basin supply approach for several global mean air temperature increases (Seglenieks and Temgoua, 2022) predicts an increase in the mean Lake Ontario water level as a result of climate change. While there is no timeframe associated with the predicted changes, the likely changes to the mean water level of Lake Ontario by 2039 are small (i.e., less than a few centimetres). Additionally, the modelling suggests that the frequency of high and low water years will also increase (i.e., more variation from year to

year) and as such short-term decreases of the water level during the Storage with Surveillance Phase are still possible. Changes will be mitigated to some extent by water level management under International Joint Commission (IJC) authority.

- Extreme weather events (intense precipitation and drought) are expected to increase (ELPC, 2019), which may lead to increased variability in Lake Ontario water levels. This is likely to increase the exchange rates between the forebay and the lake, on average.

- Earlier warming in the spring will change the seasonal pattern of surface water temperature in Lake Ontario, with warming to 10°C occurring approximately 30-45 days earlier each year by the end of the century (Ouranos, 2017). The warm spring data used in the 2017 PEA, with 10°C reached in mid-May in 2012 (vs typical mid-June, see Figure 4.4) may be considered representative of such future conditions.

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

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

5.0 Updated Tier 1 Assessment

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

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

5.1 Atmospheric Environment

5.1.1 Noise

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

5.1.2 Air Quality

5.1.2.1 Radiological Air Emissions

Stabilization Phase

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

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

<u>Storage with Surveillance Phase</u>

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

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

2015 average of $2.0x10^{12}$ Bq/year. As shown in Table 5.1, these conclusions remain applicable to the 2016-2020 average emission rates calculated from the annual EMP reports (Ecometrix, 2023).

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

Contaminant	2016-2020 Annual Emissions (1) (Bq/year)	Predicted Emissions – Storage with Surveillance (2) (Bq/year)
Tritium	$6.40x10^{14}$	$1.77x10^{14}$
Carbon-14	$2.72x10^{12}$	$2.96x10^{10}$

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

5.1.2.2 Radiological Doses from the PWMF Phase II Expansion

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

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

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

Table 5.2: Receptor Locations Considered in the Dose Rate Assessment

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

Notes:

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

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

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

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

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

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

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

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

LS07 (located to the east of the PWMF Phase II site at the shoreline) had a highest predicted annual dose of no more than 0.14 µSv/a, based on a dose rate of 1.64x10^{-3} µSv/hr and an occupancy rate of 1%, consistent with the occupancy assumed for the Sport Fisher. The 2017 PEA (Golder and Ecometrix, 2017) predicted the total radiological dose to a future Sport Fisher during the Storage with Surveillance Phase to be 0.21 µSv/a. Taking the dose from the PWMF into account, the combined dose from PNGS and PWMF for the Sport Fisher during the Storage with Surveillance Phase would be 0.35 µSv/a, well below the public dose limit.

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

Table 5.4: Dose Rates from SB3 and SB4

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

Notes:

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

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

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

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

Notes:

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

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

5.1.2.3 Non-Radiological Air Emissions

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

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

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

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

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

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

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

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

Notes:
None of the POI Concentrations exceed the 2020 or 2023 O. Reg. 419/05 Schedule 3 limits.
"-" = not available

(1) Adjusted to an annual concentration by multiplying the modelled 24-h POI concentration by a factor of $(1/365)^{0.28}$ (MOECC, 2017)
(2) Based on modelled Scenario 3 from the 2020 ESDM report, which assumes full-time operation of the Auxiliary Boiler. The modelled values in the 2020 ESDM report were used because they were higher than those modelled in 2018 or 2019 which also considered Scenario 3.

5.1.2.3.2 Canadian Ambient Air Quality Standards

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Potential Critical Group	Approx. Distance from PN (km)(1)	Wind Sector (Direction to)(1)	Transfer Parameter from Source to Air, P_{01} (s/m^3)(1)	Emission Rate (g/s)(2)	Annual Average NOx Concentration – pro-rated for Residency(3)	2020 CAAQS (annual) µg/m³	2025 CAAQS (annual) µg/m³	% 2020 CAAQS (annual)	% 2025 CAAQS (annual)
Sport Fisher	0.5	S	9.37E-06	1.39	0.13	32	23	0.4%	1%
Industrial/Commercial	0.95	NNE	2.02E-06	1.39	0.65			2%	3%
Urban Resident	1.35	WNW	9.78E-07	1.39	1.36			4%	6%
Correctional Institution	3.1	NNE	2.75E-07	1.39	0.38			1%	2%
Farm	6.9	NE	7.67E-08	1.39	0.11			0.3%	0.5%
Dairy Farm	10.25	NNE	4.94E-08	1.39	0.07			0.2%	0.3%

Notes:

(1) From 2022 ERA (Ecometrix, 2023)

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

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

5.1.3 Summary of Updated Tier 1 Assessment – Atmospheric Environment

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

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

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

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

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

5.2 Surface Water Flow and Quality

5.2.1 Surface Water Flow

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

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

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

5.2.1.1 Potential Effects on Impingement and Entrainment

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

5.2.2 Surface Water Quality

5.2.2.1 Forebay Water Quality

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

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

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

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

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

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

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

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

5.2.2.2 Lake Water Quality

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

5.2.3 Summary of Updated Tier 1 Assessment – Surface Water Environment

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

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

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

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

5.3 Sediment Quality and Transport

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

5.3.1 Sediment Transport

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

5.3.2 Sediment Quality

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

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

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

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

5.4 Groundwater

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

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

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

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

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

5.4.1 Summary of Updated Tier 1 Assessment – Groundwater

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

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

5.5 Soil Quality

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

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

5.5.1 Summary of Updated Tier 1 Assessment – Soil Quality

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

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

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

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

6.1 Ecological Conceptual Site Model

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

6.1.1 Receptor Selection

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

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

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

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

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

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

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

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

6.1.2 Assessment and Measurement Endpoints

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

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

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

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

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

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

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

6.1.3 Selection of Exposure Pathways

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

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

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

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

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

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

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

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

6.1.4 Summary of Conceptual Site Model

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

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

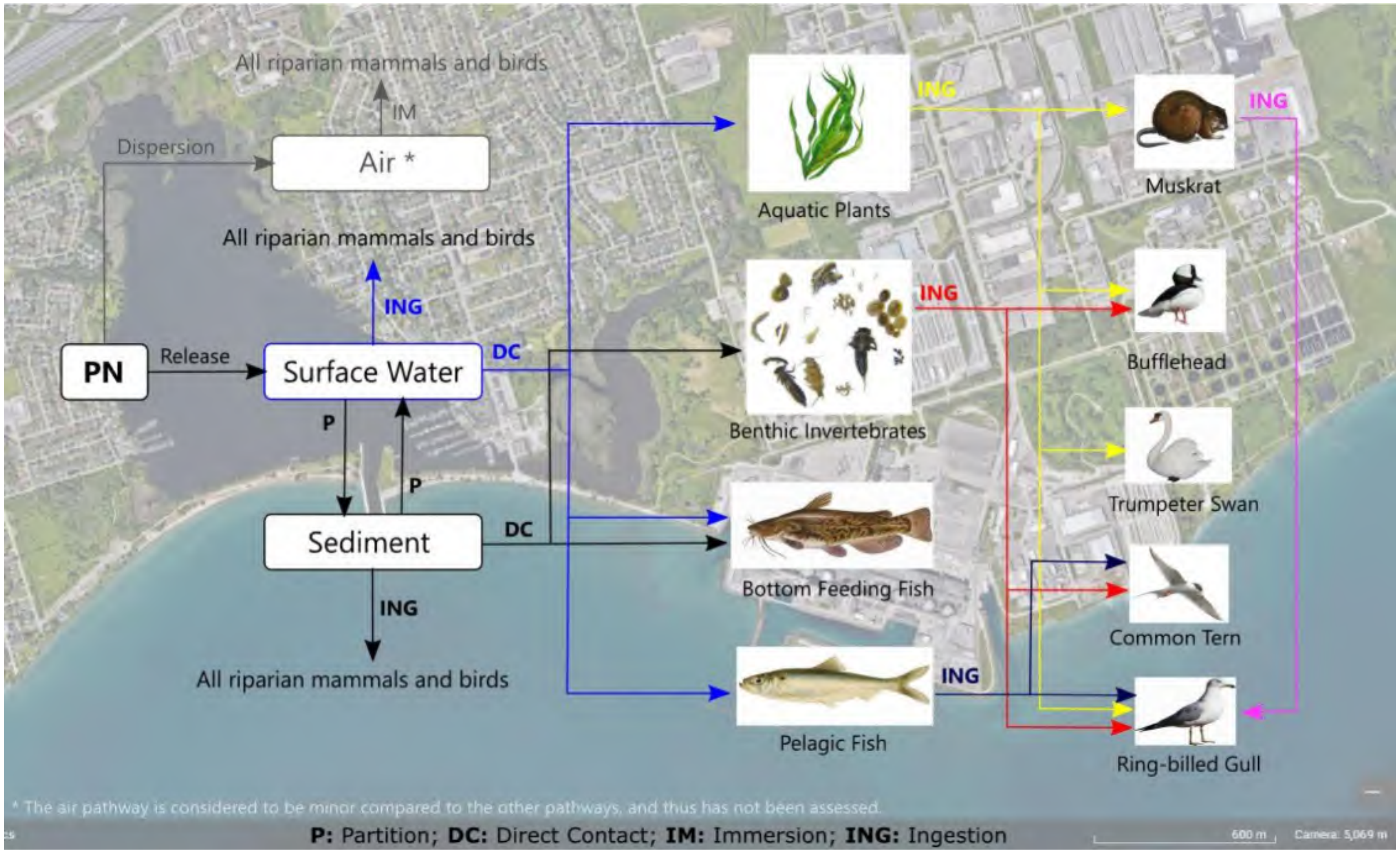


Figure 6.1: Conceptual Model for the Predictive Ecological Risk Assessment in the Forebay

6.2 Exposure Assessment

6.2.1 Exposure Point Concentrations

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

6.2.1.1 Exposure Averaging

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

6.2.1.2 Environmental Partitioning

Water to sediment partitioning is described by the following equation:

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

where,

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

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

Table 6.4: Sediment Distribution Coefficients

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

6.2.2 Exposure and Dose Calculations

6.2.2.1 Radiological Dose Calculations

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

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

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

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

where,

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

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

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

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

where,

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

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

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

6.2.2.2 Non-Radiological Dose Calculations

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

6.2.2.3 Tissue Concentration Calculations

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

$$C_t = C_m \cdot BAF$$

where,

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

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

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

where,

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

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

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

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

6.2.2.4 Exposure Factors

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

6.2.2.4.1 Body Weight and Intake Rates

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

Table 6.5: Bird and Mammal Body Weights and Intake Rates

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

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

6.2.2.4.2 Occupancy Factors

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

Table 6.6: Receptor Occupancy Factors

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

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

6.2.2.4.3 Bioaccumulation Factors

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

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

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

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

6.2.2.4.4 Transfer Factors

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

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

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

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

6.2.2.4.5 Dose Coefficients

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

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

Radionuclide	Rat		Trout		Seaweed	
	Internal DC (μGy/hr)/(Bq/kg fw)	External DC (on soil) (μGy/hr)/(Bq/m²)	Internal DC (μGy/hr)/(Bq/kg fw)	External DC (in water) (μGy/hr)/(Bq/kg ww or Bq/L)	Internal DC (μGy/hr)/(Bq/kg fw)	External DC (μGy/hr)/(Bq/kg ww or Bq/L)
Carbon-14	2.83E-05	0.00E+00	2.83E-05	1.79E-08	2.83E-05	2.17E-07
Cobalt-60	1.67E-04	7.92E-06	2.13E-04	1.29E-03	8.75E-05	1.42E-03
Cesium-134	1.71E-04	5.00E-06	2.04E-04	7.92E-04	1.13E-04	8.75E-04
Cesium-137	1.71E-04	1.88E-06	1.83E-04	2.83E-04	1.38E-04	3.29E-04
Tritium	5.76E-06	0.00E+00	5.76E-06	3.54E-13	5.76E-06	2.33E-09

Radionuclide	Tadpole		Duck		Insect Larvae	
	Internal DC (μGy/hr)/(Bq/kg fw)	External DC (in water) (μGy/hr)/(Bq/kg ww or Bq/L)	Internal DC (μGy/hr)/(Bq/kg fw)	External DC (on soil) (μGy/hr)/(Bq/m²)	Internal DC (μGy/hr)/(Bq/kg fw)	External DC (μGy/hr)/(Bq/kg ww or Bq/L)
Carbon-14	2.83E-05	2.29E-07	2.83E-05	0.00E+00	2.80E-05	8.20E-07
Cobalt-60	6.25E-05	1.42E-03	2.38E-04	7.50E-06	5.20E-05	1.40E-03
Cesium-134	9.58E-05	9.17E-04	2.21E-04	5.00E-06	7.20E-05	9.20E-04
Cesium-137	1.33E-04	5.42E-07	1.88E-04	1.79E-06	9.80E-05	3.70E-04
Tritium	5.76E-06	1.33E-11	5.76E-06	0.00E+00	5.78E-06	2.40E-13

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

6.2.2.4.6 Specific Activity Model for Tritium

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

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

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

or

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

where,

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

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

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

or

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

where,

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

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

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

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

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

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

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 N288.1-20 (CSA, 2020)

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

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

where,

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

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

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

where,

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

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

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

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

where,

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

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

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

Table 6.11: Input Parameters for Specific Activity Calculations for Tritium

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

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

6.2.2.4.7 Specific Activity Model for Carbon-14

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

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

where,

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

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

Table 6.12: Stable Carbon Content for Food Types

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

6.2.3 Models

6.2.3.1 IMPACT model

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

6.2.3.2 Forebay Discharge Modelling

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

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

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

6.2.3.2.1 Model Description

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

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

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

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

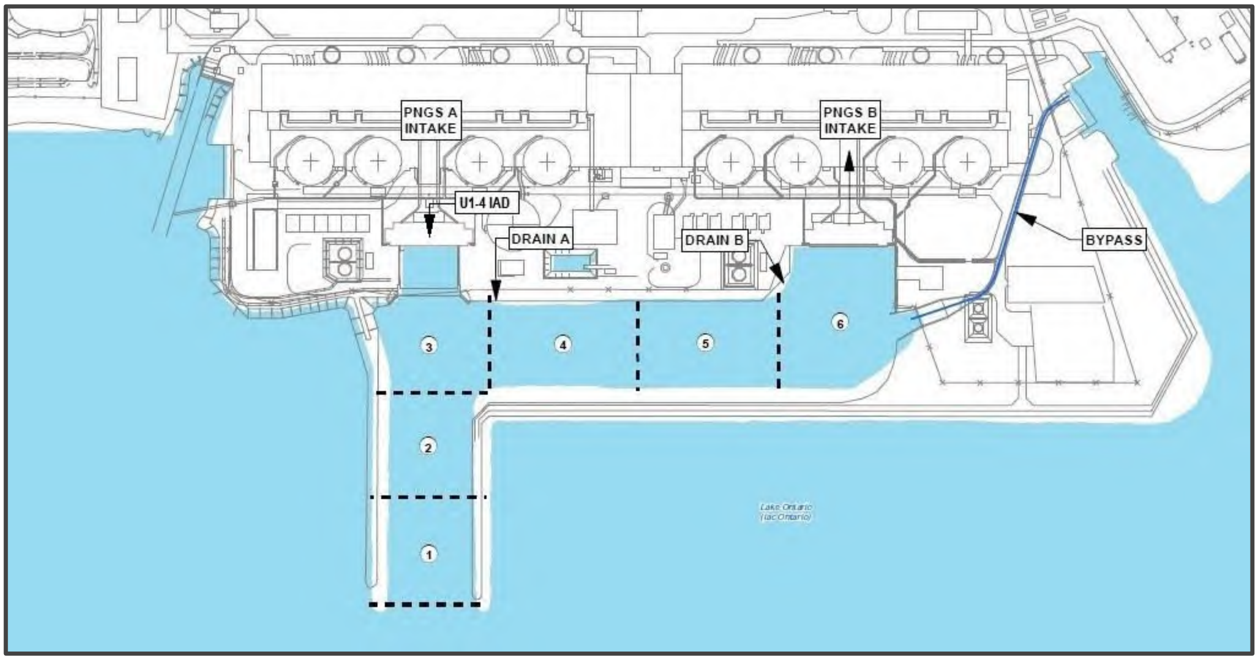


Figure 6.2: Schematic of the Updated Forebay Box Model

Table 6.13: Flows Used in the Updated Forebay Model

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

6.2.3.2.2 Results

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

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

Table 6.14: Summary of Average Forebay Concentration Factors

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

Notes:

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

Table 6.15: Summary of Predicted Forebay Current Speeds

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

Notes:

A positive current speed represents flow from the forebay intake towards the PNGS B intake. A negative current speed represents a flow from the PNGS B intake towards the lake.

The values presented in the table represent statistical values and do not necessarily occur at the same time.

6.2.4 Exposure Point Concentrations and Doses

6.2.4.1 Exposure Point Concentrations

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

Table 6.16: Environmental Media Concentrations in the Forebay

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

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

Table 6.17: Radiological Tissue Concentrations by Receptor

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

6.2.4.2 Exposure Doses

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

6.2.5 Uncertainties in the Exposure Assessment

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

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

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

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

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

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

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

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

6.3 Effects Assessment

6.3.1 Radiation Benchmarks

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

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

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

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

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

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

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

6.3.2 Uncertainties in the Effects Assessment

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

6.4 Risk Characterization

6.4.1 Risk Estimation

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

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

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

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

6.4.2 Discussion of Radiation Effects

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

6.4.3 Entrainment/Impingement

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

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

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

Table 6.19: Fish Swim Speeds for Local Species

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

Source: (Katopodis and Gervais, 2016)
Notes:
a. Data for Family Ictaluridae
b. Data for Genus *Prosopium*
c. Data for Genus *Anguilla*

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

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

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

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

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

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

6.4.4 Uncertainties in the Risk Characterization

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

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

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

7.0 Environmental Monitoring and Protection Programs

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

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

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

Table 7.1: Monitoring Programs through Stabilization and Storage with Surveillance

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

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

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

8.0 Conclusions

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

8.1 Tier 1 Assessment Conclusions

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

Radiological Air Emissions

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

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

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

Radiological Air Emissions – Pickering Waste Management Facility Phase II Expansion

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

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

Non-Radiological Air Emissions

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

Surface Water Flow and Quality

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

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

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

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

Sediment Quality and Transport

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

Groundwater

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

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

Soil Quality

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

8.2 Tier 2 Assessment Conclusions

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

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

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

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

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

8.3 Additional Risk Management Recommendations

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

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

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

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Appendix A Screening Tables

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

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

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

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

Notes:

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

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

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

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

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

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

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

Notes:

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

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

(1°-4°) = Benchmark Screening Heirarchy

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

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

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

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

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

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

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

Notes:

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

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

(1°-4°) = Benchmark Screening Heirarchy

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

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

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

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

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

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

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

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

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

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

B.1 Introduction

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

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

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

- Table B.1 provides the bounding airborne tritium emissions in the Storage with Surveillance Phase, including all assumptions relating to potential tritium sources and streams;

- Table B.2 provides the bounding airborne C-14 emissions in the Storage with Surveillance Phase, including and all assumptions relating to potential C-14 sources and streams; and

- Table B.3 provides more details/justifications on bounding tritium emission estimates used for selected streams in Table B.1.

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

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

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

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

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

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

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

Notes:

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

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

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

Notes:

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

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

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

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

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

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

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

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

B.4 Conclusion

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

B.5 References

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

Appendix C Sample Calculations

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

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

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

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

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

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

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

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